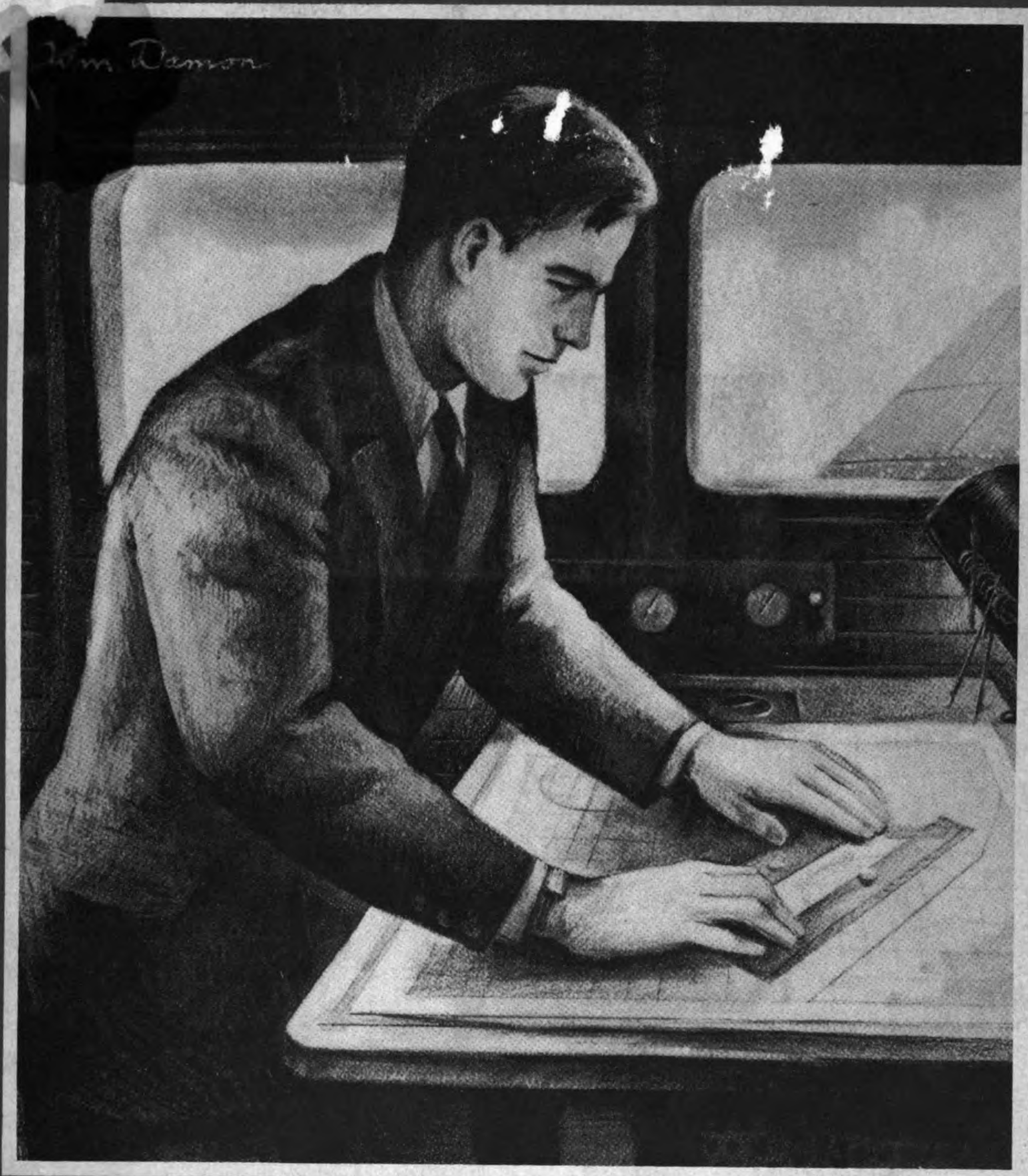
NAVIGATION



PRINCIPLES

AIRLINES WAR TRAINING INSTITUTE

NAVIGATION PRINCIPLES

PREPARED FOR AIRCRAFT FLIGHT CREWS

AIRLINES WAR TRAINING INSTITUTE
1740 G Street, N. W.
Washington, D. C.

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Preparation
ELBERT F. BLACKBURN

Illustration
WILLIAM DAMON

IMPORTANT

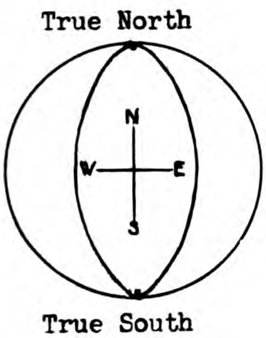
This material was not prepared for home study. It was prepared for use by student and instructor in the classroom and in drafting board periods.

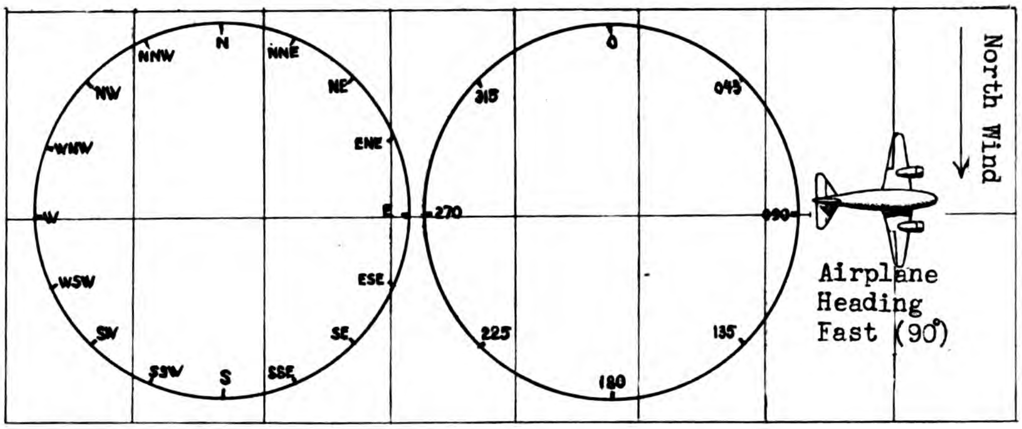
Each grouped section below represents about one hour of lecture. However, Navigators have extensive drafting board periods daily. It is recommended that many of the classroom problems be done in these periods. Eight of the lectures should be given during drafting board periods at the instructor's discretion to suit the suggested schedule in the "Flight Crew Training Program". This is particularly true in the late stages. Examinations are given in the drafting board periods.

C O N T E N T S

NAVIGATION PRINCIPLES

TRUE DIRECTIONS





True directions are always considered relative to the Earth's true north pole, thus: North, Northeast, East, Southeast, or 000°, 045°, 090°, 135°, etc. When an aircraft heads East its <u>nose is pointed</u> toward East. An East wind blows <u>from</u> East.

EXAMPLE PROBLEMS

1. An airplane is maintaining a heading of West. How can this be expressed in degrees?

   ANS: West is 270°.

2. An East wind is blowing. Express this in degrees FROM WHICH THE WIND IS BLOWING.

   ANS: 090°. Winds are always shown in degrees from which the wind blows and measured in relation to True North. Wind arrows <u>fly with the wind</u>.

CLASSROOM PROBLEMS

1. An airplane is flying on a True heading of 090°. The wind is also 090°. Does the wind help or hinder?

   ANS:______________________________

2. Express WNW in degrees.

   ANS:______________________________

3. Express SSW in degrees.

   ANS:______________________________

ACTION OF WIND ON AIRCRAFT

A free balloon drifts with the wind. A boat being rowed across a river drifts downstream with the current. An aircraft flying cross-country is likewise effected by the wind in which it flies and drifts with it.

EXAMPLE PROBLEMS

1. Could you tell by the "feel" of the aircraft if there is a strong wind acting upon it in flight?

   ANS: No. It may be rough (turbulent) but strong winds can blow and cause no sensation in the airplane itself.

2. Would you be justified in assuming the wind to be constant at all altitudes?

   ANS: Definitely not. It is possible for the wind to blow 100 miles per hour at 20,000 feet while little or no wind blows at the ground.

3. Would you expect the wind direction, at all altitudes over a certain point, to remain constant?

   ANS: Generally there is little variation in wind direction from the surface to 2,000 ft. Above 2,000 ft. it may change to any direction.

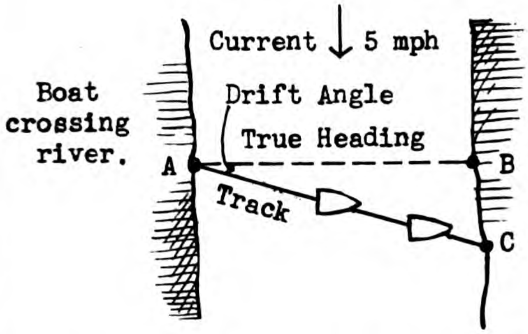
CLASSROOM PROBLEM

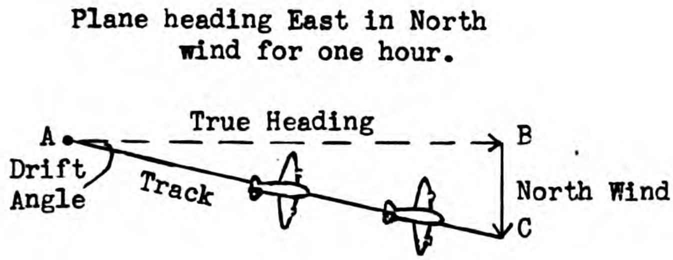
1. What surface indications over land or water would show the presence of wind? Name three.

   ANS:____

   ____

GRAPHIC EXAMPLE OF THE EFFECT OF WIND





A boat leaves the river bank at "A" and heads directly toward "B" but arrives at "C" because of current. If an aircraft leaves "A" and heads for "B", where it would normally arrive after an hour of flight in still air, it will arrive at "C" at the end of the hour because of the North wind.

EXAMPLE PROBLEMS

1. How far downstream will a boat be forced in one hour if the current flow is 10 miles per hour?

   ANS: 10 miles.

2. How far downwind will a plane be forced in an hour if the velocity of the wind is 10 miles per hour?

   ANS: 10 miles.

3. What TRACK (path over the ground) is followed by the plane in the diagram above?

   ANS: The TRACK is shown by the line A-C.

4. What GROUNDSPEED (speed over the ground) was made by the plane above?

   ANS: GROUNDSPEED is the track distance divided by time. The distance above is A-C. The time is one hour. Thus, if A-C is found to be 150 miles, the GROUNDSPEED would be 150 miles per hour.

CLASSROOM PROBLEMS

1. Is GROUNDSPEED always measured along the TRACK?

   ANS:____

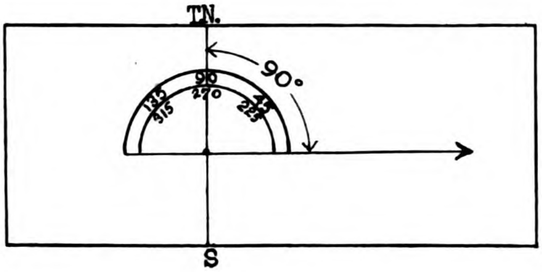
2. Along what line is AIRSPEED (speed through the air) measured?

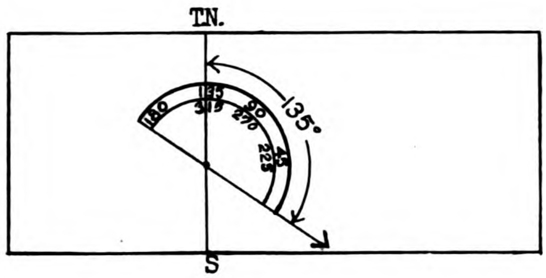
   ANS:____

3. Is AIRSPEED <u>ever</u> measured along the track? If so, when?

   ANS:____

PROTRACTOR FOR MEASURING ANGLES





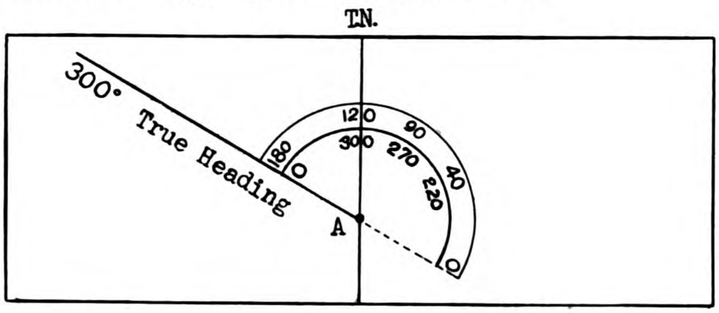
In order to show the performance of aircraft under various wind conditions, accurate headings, tracks, and wind directions should be laid down graphically. Use the Protractor as shown above to measure the correct angles. Place the center of Protractor on line representing true north-south. Rotate Protractor until desired direction is located on north-south line above the center point.

NOTE: All Protractors are not numbered identically. Study the markings carefully.

EXAMPLE PROBLEMS

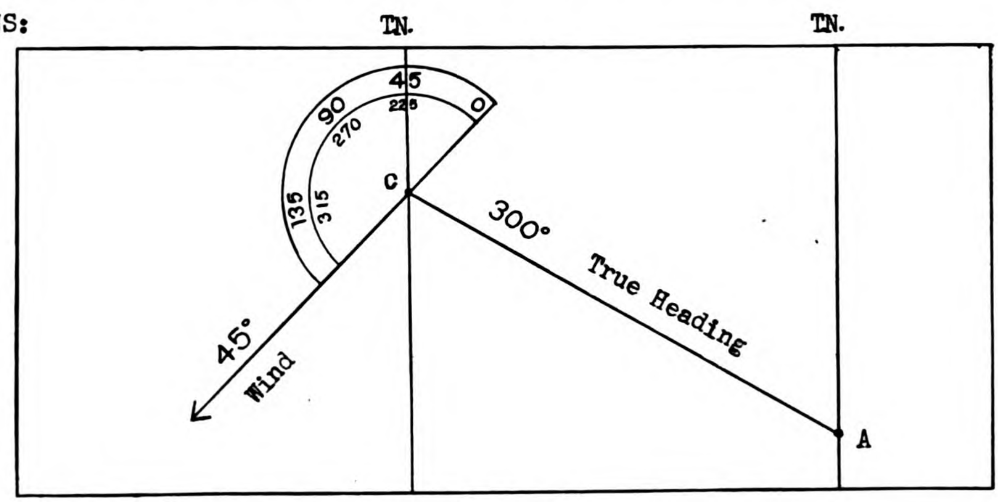
1. Lay down a true heading of 300° from point "A".

ANS:



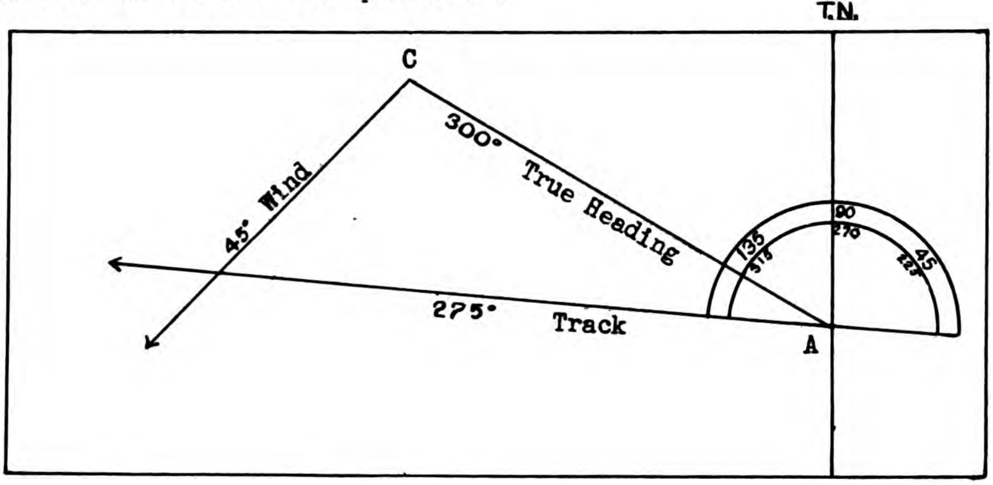
2. Label the true heading A-C and at C show a 045° wind.

ANS:



3. Lay down a track of 275° from point "A".

ANS:



CLASSROOM PROBLEMS

1. Lay down a true heading of 060° and a track of 050° from a point "A".

ANS:

2. Lay down a true heading of 177° and a track of 185° from a point "B".

ANS:

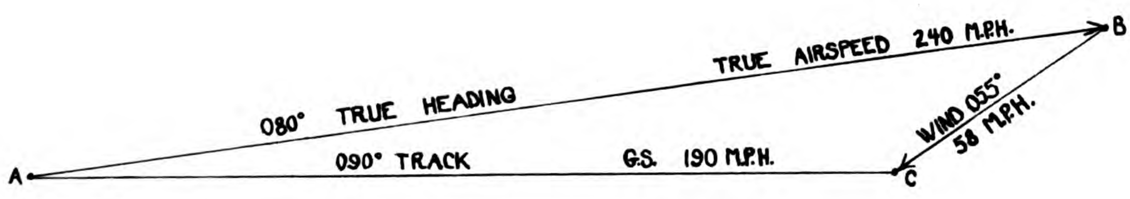
3. Lay down a wind direction of 135° from a point "C" on the true heading line of the above problem.

ANS:

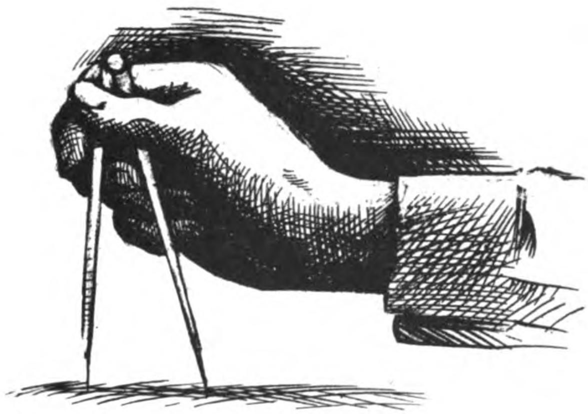
4. Lay down a true heading of 275° and a track of 260° from a point "X". From a point "C" on the true heading line, show a wind of 030°.

ANS:

RULER AND DIVIDERS FOR MEASURING VELOCITIES



An ordinary ruler scale may be used to measure the length of the sides of the triangle representing airspeed, groundspeed and wind velocity. In the diagram above, one inch was used to represent 40 miles, and the length of the ruler scale was picked off with a pair of dividers.



The dividers are to be used with <u>one hand, only</u>. Notice the position of the thumb. Keep your hand out of your line of vision so that the points are clearly visible.

In opening or closing the dividers, keep one blade pressed against the palm of the hand and use the middle and index fingers to move the other blade.

EXAMPLE PROBLEM

1. In the second illustration above, the dividers are measuring two inches. If a scale of 40 miles to an inch is used, how many miles are represented between divider points?

   ANS: 80 miles.

CLASSROOM PROBLEMS

1. Allow 40 miles to an inch and scale the following distances: 120, 175, 135, 205.

   ANS:

2. Allowing 40 miles to an inch, how many miles are represented by: 3/4 inch, 1-1/2 inches, 2-3/4 inches, 3-1/2 inches and 5-3/4 inches?

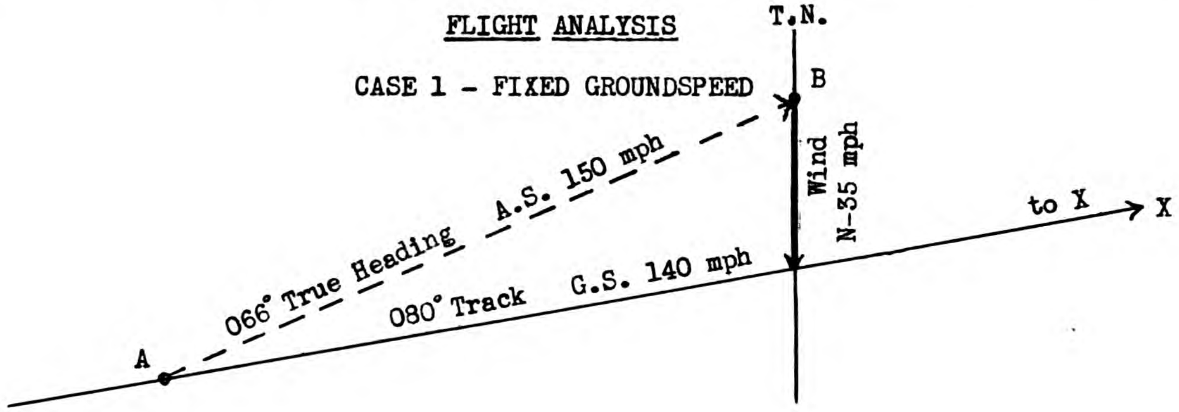
   ANS:____

3. Represent graphically the following problem: A plane left point "A" on a true heading of 100°, at a true airspeed of 160 MPH. It proceeded for one hour during which time a wind of 050°-40MPH acted. What track and groundspeed was made good? How many degrees sideways did the aircraft drift?

   ANS:

FLIGHT ANALYSIS

CASE 1 - FIXED GROUNDSPEED

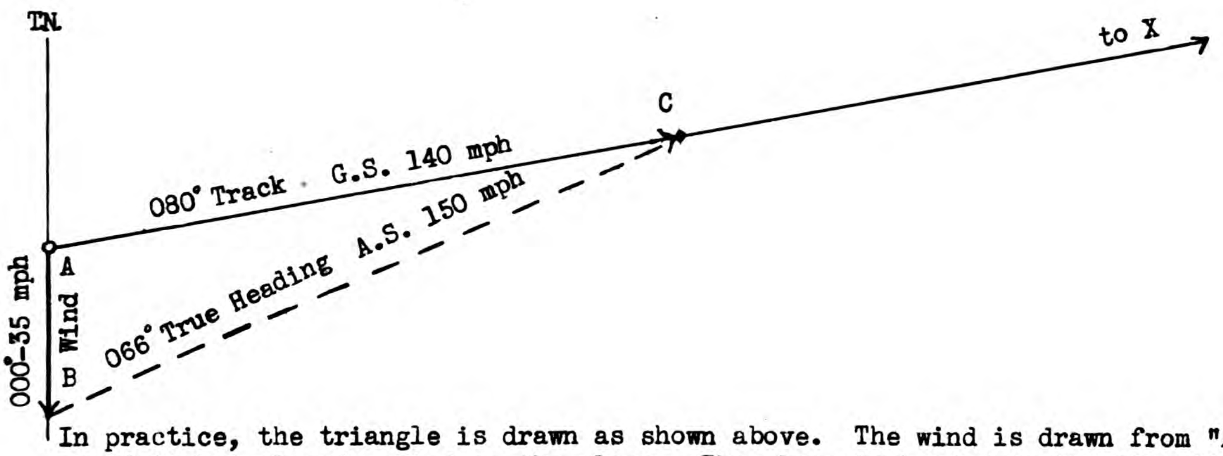


Whenever the navigator has knowledge of the wind, he must make allowance for it, not only when executing a flight, but when analyzing and planning a projected flight.

A plane must go from A to X at a fixed groundspeed of 140 MPH. The track is to be 080°. The wind is North 35 MPH. It is the navigator's duty to determine the true heading and airspeed for the plane. The correct values are shown in the diagram.

This is a common problem where time-table schedules must be met, especially in domestic airline operation.

CASE 1 - FIXED G.S. (redrawn)

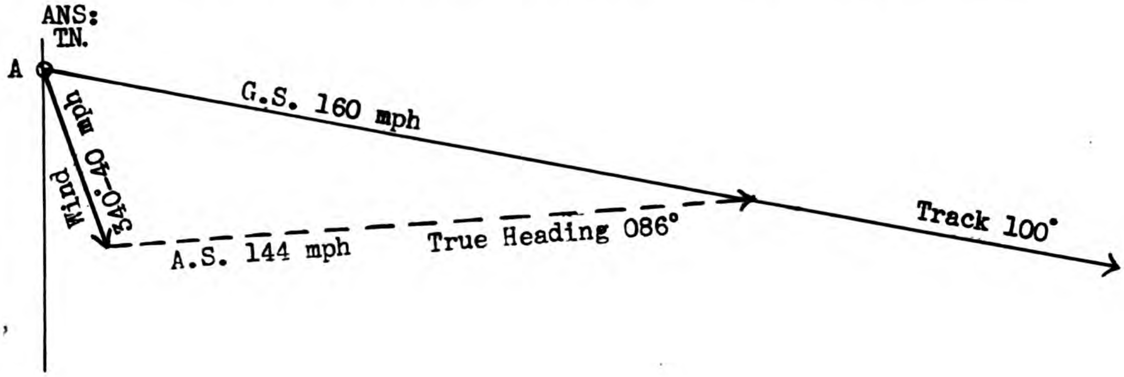


In practice, the triangle is drawn as shown above. The wind is drawn from "A" as if it had already acted on the plane. The plane is headed in the direction B-C so as to overcome the wind and arrive at point "C" on time. The lengths and directions of the sides agree with those of the previous sketch.

EXAMPLE PROBLEMS

1. A plane must make a schedule of 160 MPH on track 100° from point A. The wind is 340°-40 MPH. What true heading and airspeed must be maintained?

ANS:

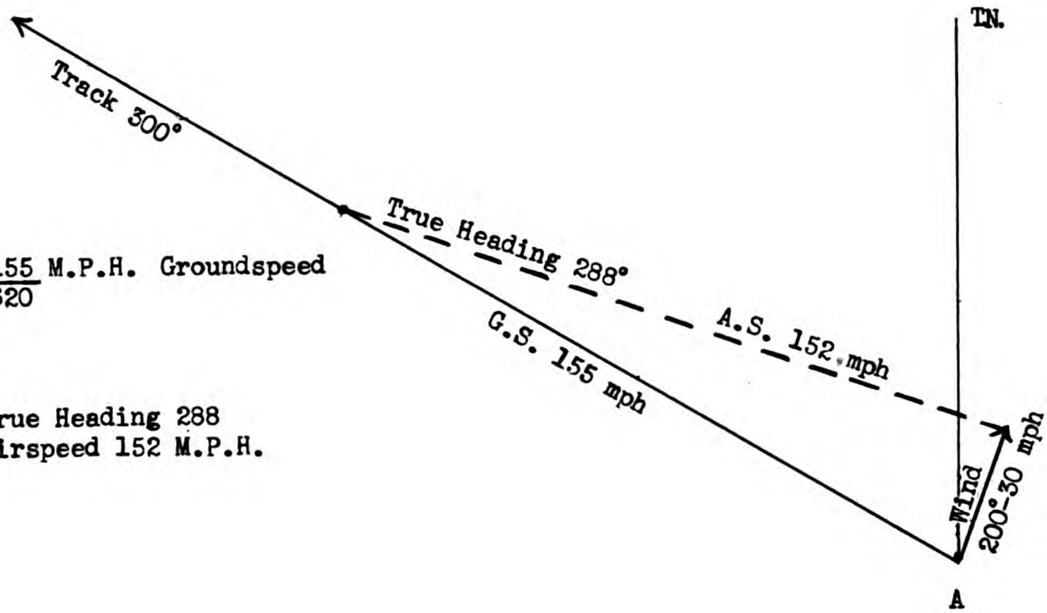


2. A plane must make a trip of 620 miles in 4 hours. The track is 300° and the wind is 200°-30 MPH. What true heading and airspeed must be maintained?

ANS:

$$4\overline{)620}\quad 155$$ M.P.H. Groundspeed

True Heading 288
Airspeed 152 M.P.H.



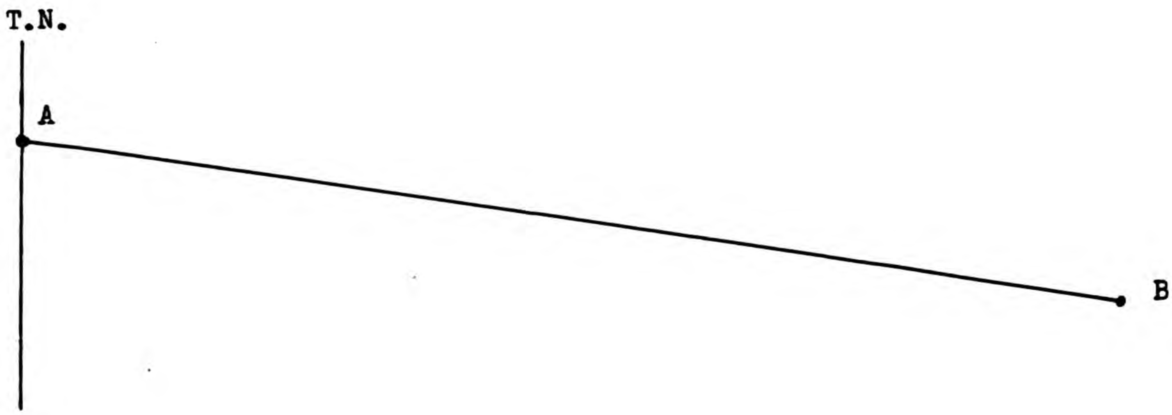
CLASSROOM PROBLEMS

1. A plane is required to make a 550 mile flight from airport "A" in 3-1/3 hours. The track is 240° and the wind is 280°-40 MPH. What true heading and air-speed must be maintained? This problem must be done graphically. No computer is to be used.

   ANS:

2. A navigator is required to obtain the true heading and airspeed for the following flight from A to B. The allowable flight time is 1.5 hours. The wind is 030°-50 MPH. Use a scale of 40 miles to an inch.

   ANS:



3. A plane is ordered to make a schedule of 150 MPH on track 050°. The wind is 000°-20 MPH. What true heading and airspeed must be maintained?

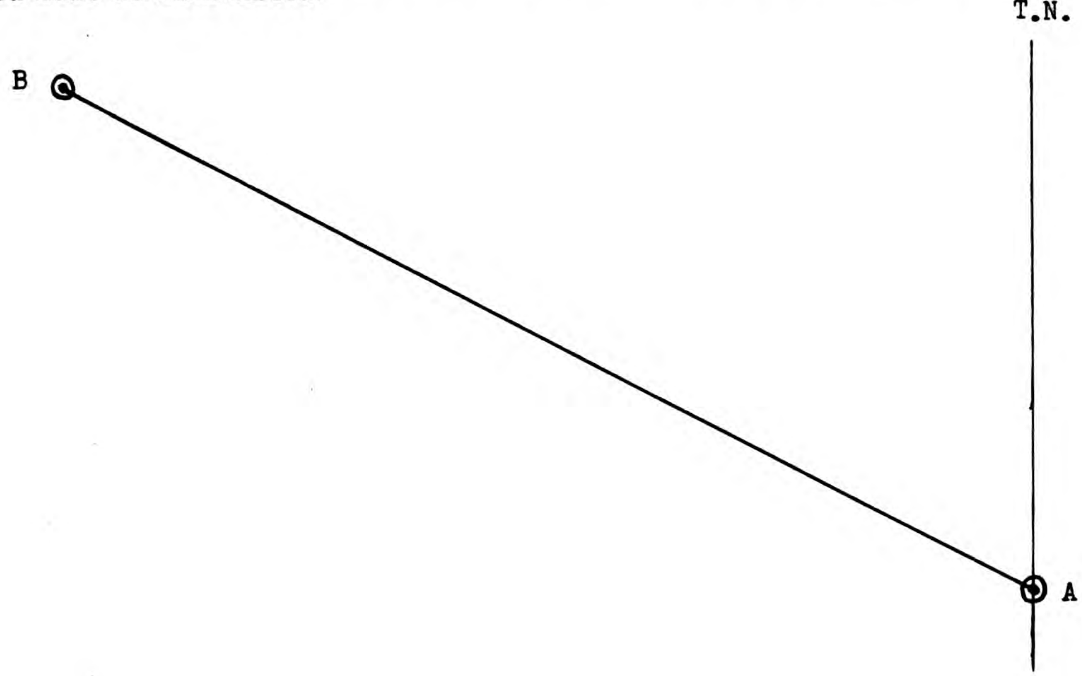
ANS:

4. A plane is ordered to make 125 MPH on track 175°. The wind is 210°-50 MPH. (a) What true heading and airspeed must be maintained? (b) If the plane turns back, what true heading and airspeed will have to be maintained to make the same G.S.?

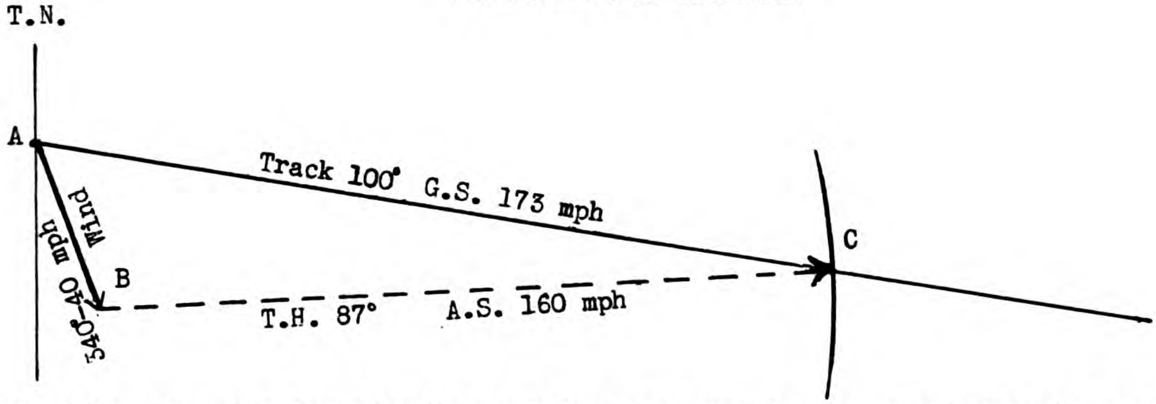
ANS: (a) (b)

5. A plane is required to make 140 MPH between "A" and "B" on the track shown in the following sketch. The wind is 220°-15 MPH. What true heading and airspeed must be maintained?

ANS:



CASE 2 - FIXED AIRSPEED

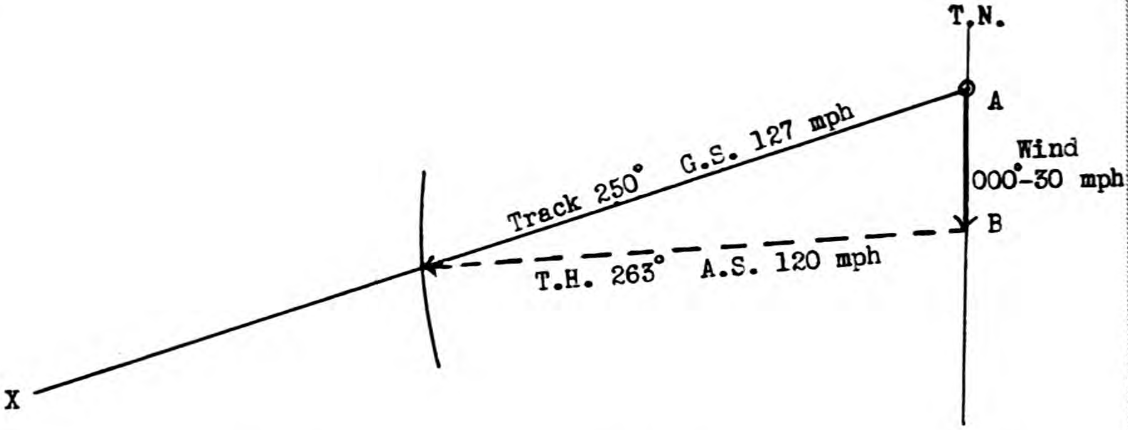


In this case, the plane is flown at its best cruising airspeed regardless of the resulting groundspeed. The plane is flying on track 100°. The wind is 340°-40 MPH. The airspeed is 160 MPH. To determine the true heading to be maintained and the groundspeed that will be made, swing an arc representing the airspeed from "B" until it crosses the track line. The length of the line A-C represents the groundspeed. The direction of the line B-C represents the true heading to be maintained.

EXAMPLE PROBLEMS

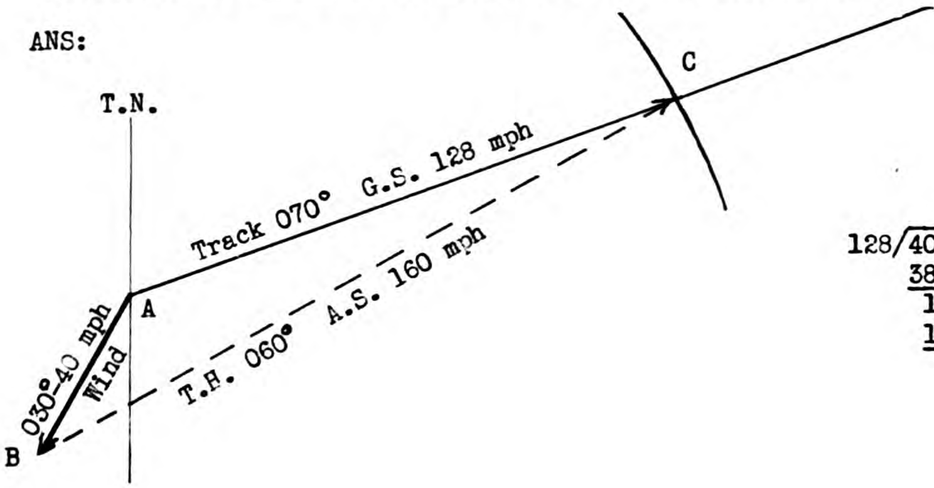
1. A plane is ordered to fly from A to X at an airspeed of 120 MPH. The track is 250°. The wind is 000°-30 MPH. What groundspeed will be made? What true heading will be maintained?

ANS:



2. A plane is ordered to fly 400 miles on track 070°. The airspeed is 160 MPH. The wind is 030°-40 MPH. What true heading must be maintained? What groundspeed will be made and how long will it take to make the flight?

ANS:




```
      3.12 hours flight
128/400
    384
     160
     128
      320
```

CLASSROOM PROBLEMS

1. A plane is dispatched on track 130°. The navigator is instructed to fly at 4,000 ft. where the wind is 030°-30 MPH. At 4,000 ft., the best cruising airspeed is 165 MPH. What groundspeed and true heading will be maintained?

   ANS:

2. Another plane of the same type is dispatched over the same route at 6,000 ft. where the wind is 050°-35 MPH. At 6,000 ft. the best cruising airspeed is 170 MPH. What groundspeed and true heading will be maintained?

   ANS:

3. A third plane of the same type is dispatched over the same route at 8,000 ft. where the wind is 070°-40 MPH. At 8,000 ft. the best cruising airspeed is 180 MPH. What groundspeed and true heading will be maintained?

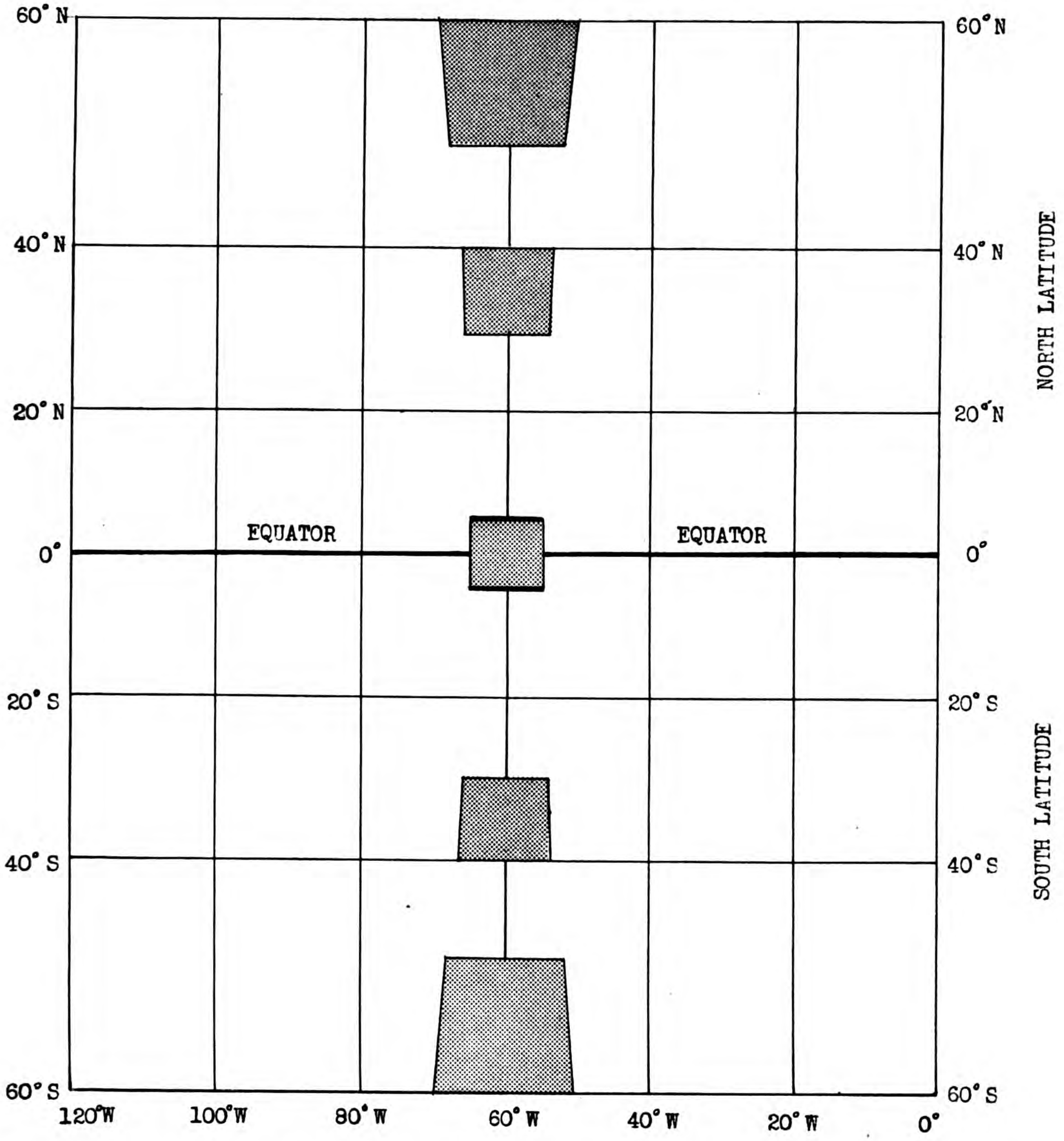
   ANS:

4. Review the last three problems. At what altitude will the quickest flight be made?

ANS:____

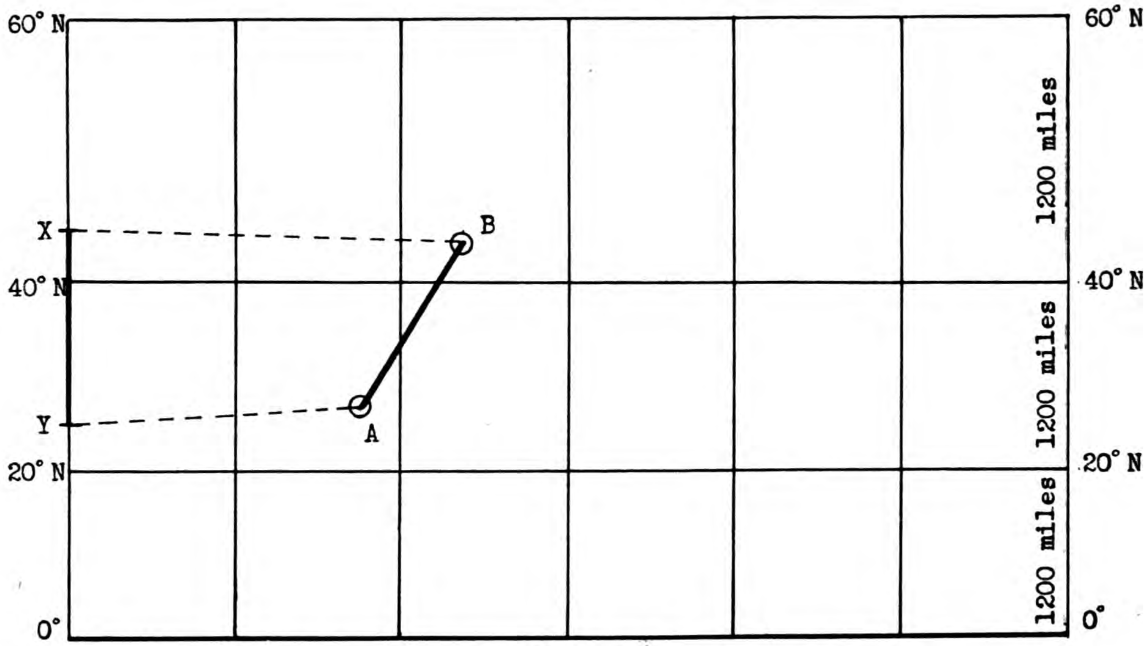
CHART CHARACTERISTICS AND USAGE

MERCATOR PROJECTION



No flat chart can be devised that will show a large portion of the round earth without distortion. Some areas are always stretched or shrunk out of their original shape. The MERCATOR CHART (or map), shown above, has this characteristic. Each of the shaded areas shown contains the same number of square miles.

MERCATOR DISTANCES



One nautical mile is 1/60 part of a degree of latitude. 20° of latitude measured straight north toward the pole is always equal to 1200 nautical miles.

On a MERCATOR chart 1200 miles at the equator is shown by a line just half as long as the line representing 1200 nautical miles at 60° north latitude. Because of this, distances measured in any area of a MERCATOR chart must always be measured against the milage scale for that same area. This milage scale is always the latitude scale, left or right, of the area in which the distance is measured.

On the chart above, the distance A-B is first picked off with a pair of dividers and then placed against the X-Y portion of the latitude scale on the left (or right) side of the chart.

EXAMPEL PROBLEMS
(Use H.O. chart #VP-102 or the equivalent)

1. What is the distance between Richmond, Va., and Baltimore, Md.?

   ANS: 113 nautical miles. (Use black dots representing the cities.)

2. What is the distance between Richmond, Va., and Philadelphia, Pa.?

   ANS: 180 nautical miles.

3. What is the distance between Norfolk, Va., and Bermuda? (Use center of island.)

   ANS: 631 nautical miles.

CLASSROOM PROBLEMS
(Use H.O. chart #VP-102 or the equivalent)

1. What is the distance between Philadelphia, Pa., and Boston, Mass.?

ANS: ____________________

2. What is the distance between Boston, Mass., and Halifax, Nova Scotia?

ANS: ____________________

3. What is the distance between New Haven, Conn., and Portland, Me.?

ANS: ____________________

4. What is the distance between Portland, Me., and Bangor, Me.?

ANS: ____________________

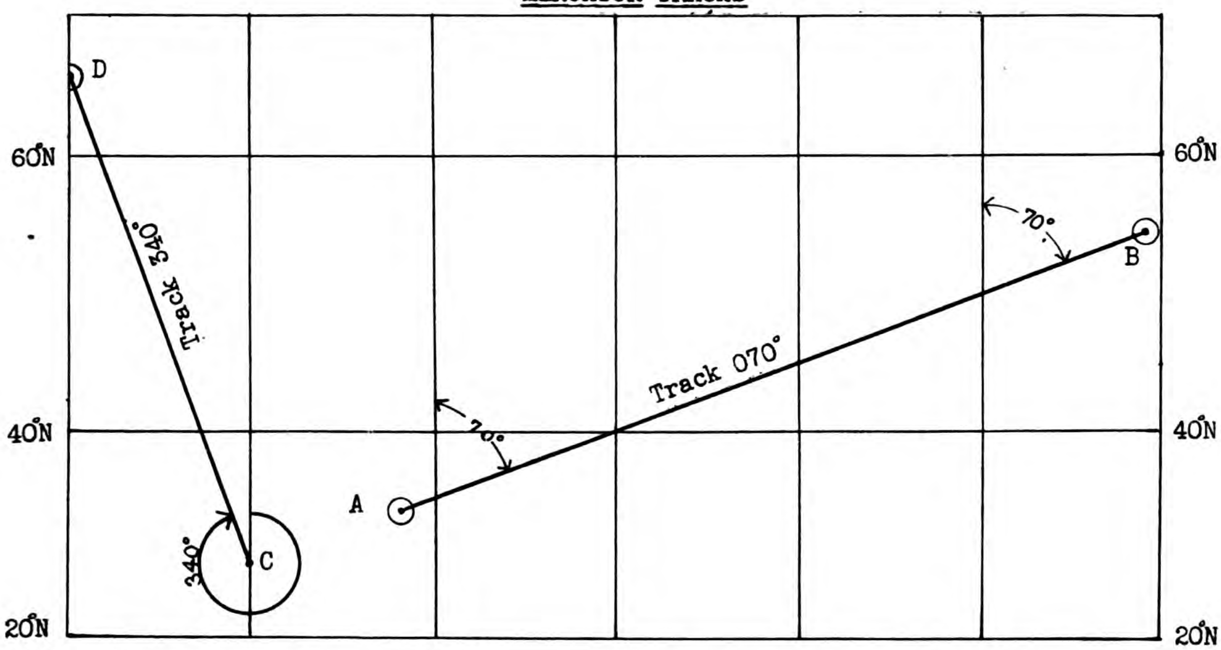
5. What is the distance between Bangor, Me., and Halifax, Nova Scotia?

ANS: ____________________

6. What is the distance between Halifax, Nova Scotia, and Shediac, New Brunswick?

ANS: ____________________

MERCATOR TRACKS



All vertical lines (meridians) run true north and south. All horizontal lines, latitude 20°, 60°, etc., run true east and west. Tracks are reckoned clockwise from the true north-south meridians. The track from A to B is 70°. The track from C to D is 340°. Mercator tracks cross all meridians at the same angle.

EXAMPLE PROBLEMS

1. What is the mercator track from Norfolk, Va., to Bermuda? (Center of Island.)

   ANS: 116°

2. What is the track from Halifax, Nova Scotia, to Boston, Mass.?

   ANS: 247°

CLASSROOM PROBLEMS

1. What is the track from Washington, D. C., to New Haven, Conn.?

   ANS:______________________________

2. What is the track from New Haven, Conn., to Portland, Me.?

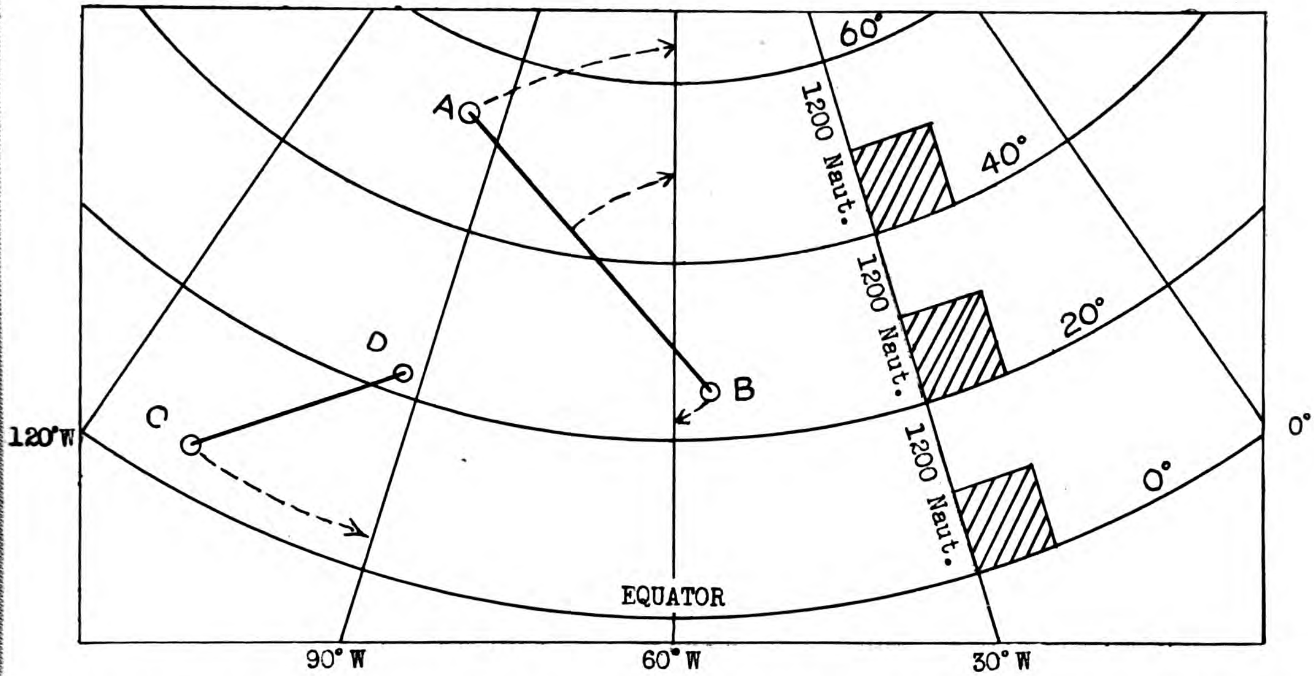
   ANS:______________________________

3. You are ordered to fly from Halifax, Nova Scotia, to Bangor, Me. The best cruising airspeed for your plane is 160 MPH. The wind is 300°-40 MPH. How long will it take to make the trip?

   ANS:______________________________

AIRWAY CHART
(Lambert Projection)

LAMBERT CHART DISTANCES



The distortion of areas on this chart is not severe (see the shaded equal areas). The latitude scale (nautical mileage scale) for one area may be used for another without great error, but if the distance is more than 100 miles, it should be scaled against the latitude scale for that area. Remember that one nautical mile is 1/60 of a degree of latitude.

The arrows near lines A-B and C-D show where the nautical mileage between these points should be scaled.

EXAMPLE PROBLEMS
(Use U.S.C.& G.S. airways chart #3060-B or equivalent)

1. What is the distance between Memphis, Tenn., and Evansville, Ill.?

   ANS: 208 nautical miles. (Center of city to center of city.)

2. What is the distance from Evansville, Ill., to Toronto, Canada?

   ANS: 505 nautical miles.

3. What is the distance from Toronto, Canada, to Quebec, Canada?

   ANS: 395 nautical miles.

CLASSROOM PROBLEMS
(Use U.S.C.& G.S. airways chart #3060-B or equivalent)

1. What is the distance in nautical miles from New Orleans, La., airport to Key West, Fla.?

ANS:______________________________

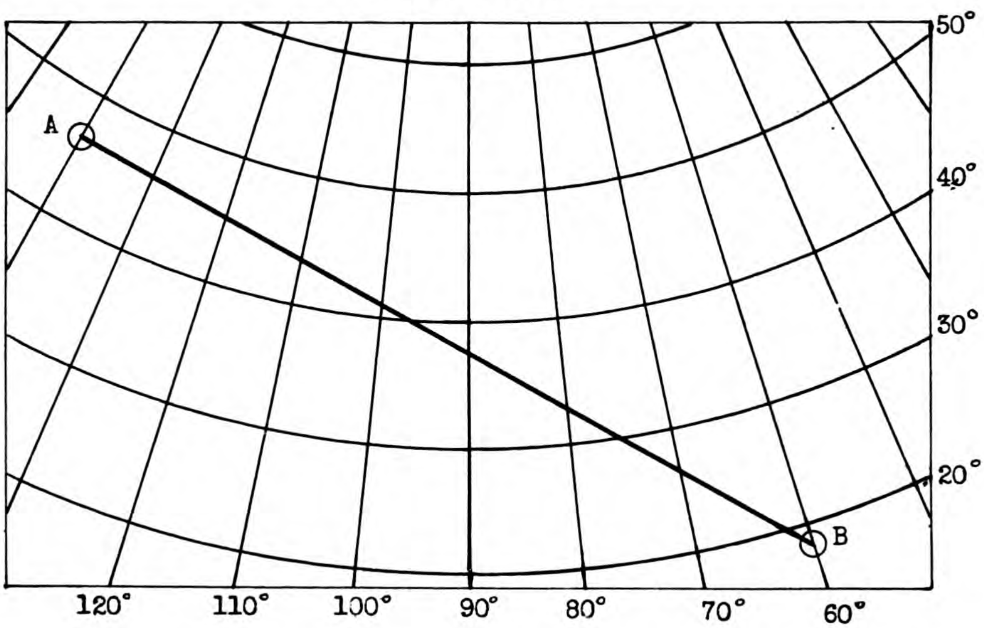
2. What is the distance in nautical miles from New Orleans, La., airport to Oklahoma City airport?

ANS:______________________________

3. What is the distance in nautical miles from Oklahoma City, Okla., airport to Kansas City, Kan., airport?

ANS:______________________________

LAMBERT TRACKS



All parallels of latitude running east-west appear as concentric circles.

All meridians of longitude (north-south lines) converge toward the pole.

Because the meridians are not parallel on this chart, the track line from A to B crosses each meridian at a slightly different angle from the angle at which it crossed the preceding meridian. Hence, the track line A-B is constantly changing in direction.

In practice, a navigator wishing to follow the line A-B should break the entire line A-B into a series of short legs each of which crosses FOUR DEGREES of longitude. The track for each leg is then measured relative to the middle meridian through that leg.

EXAMPLE PROBLEMS

(Use U.S.C.& G.S. airways chart #3060-B or equivalent)

1. You are ordered to proceed from Miami, Fla., to Corpus Christi, Texas. What <u>tracks</u> should be followed?

   ANS: From Miami to longitude 84° west.....282°
   From long. 84° to long. 88°..........280°
   From long. 88° to long. 92°..........277°
   From long. 92° to long. 96°..........275°
   From long. 96° to Corpus Christi.....273°

2. What is the merit of such a series of tracks over a single Mercator track?

   ANS: The distance along these tracks is a little shorter than it would be if a single Mercator track were followed.

3. Are the legs of equal length?

   ANS: No, not even those that cover four degrees of longitude, each.

4. What Lambert tracks should be followed from Denver, Colorado, to Winnipeg, Canada?

   ANS: From Denver to long. 101° west.......027°
   From long. 101° to Winnipeg..........029°

5. What Lambert tracks should be followed from Chicago, Ill., to New Orleans, La.?

   ANS: Track 189° all the way.

CLASSROOM PROBLEMS

(Use U.S.C.& G.S. airway chart #3060-B or equivalent)

1. What Lambert tracks should be followed from Stevenson Airport (Winnipeg, Canada) to Malton Airport (Toronto, Canada)?

   ANS:

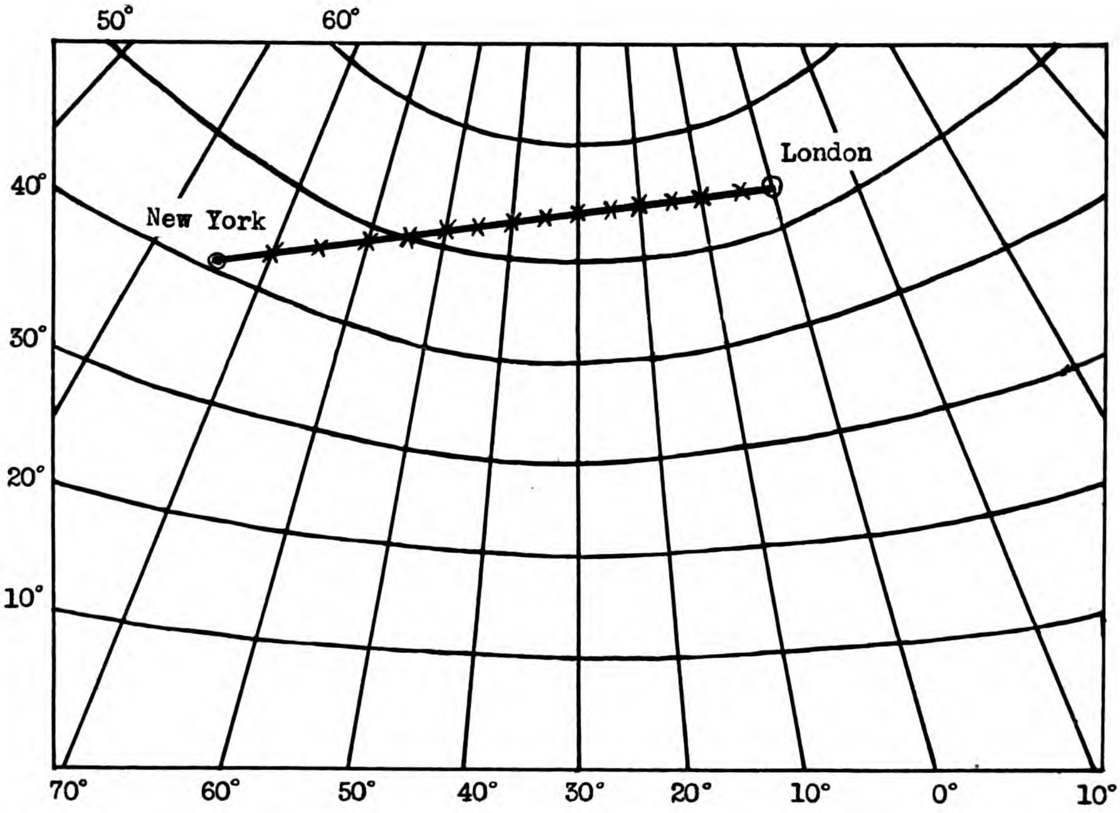
2. What Lambert tracks should be followed from Winnipeg to Quebec?

   ANS:

3. What Lambert tracks should be followed from Monterry, Mexico, to Denver, Colorado?

ANS:

GREAT CIRCLE TRACKS AND DISTANCE



This GREAT CIRCLE chart is only intended to be used for planning purposes. The chart has one great advantage over any other, insofar as a straight line drawn on it represents the VERY SHORTEST possible track between two points.

After this track has been laid down the navigator notes the exact latitude at which it crosses every fifth degree of longitude. These points are transferred to a flight chart such as the Mercator chart and the points, when connected, reproduce the short track to be followed.

The tracks of the various legs thus laid down should be measured relative to the Mercator meridians. The lengths of the various legs should be determined by means of the proper Mercator latitude scale.

EXAMPLE PROBLEMS

1. What is a great circle?

   ANS: A great circle on the earth is a circle that would be formed by passing a plane through the center of the earth.

2. Are the meridians great circles?

   ANS: Yes.

3. Are the latitude parallels also great circles?

   ANS: Only the 0° parallel (equator). The other parallels form "small circles".

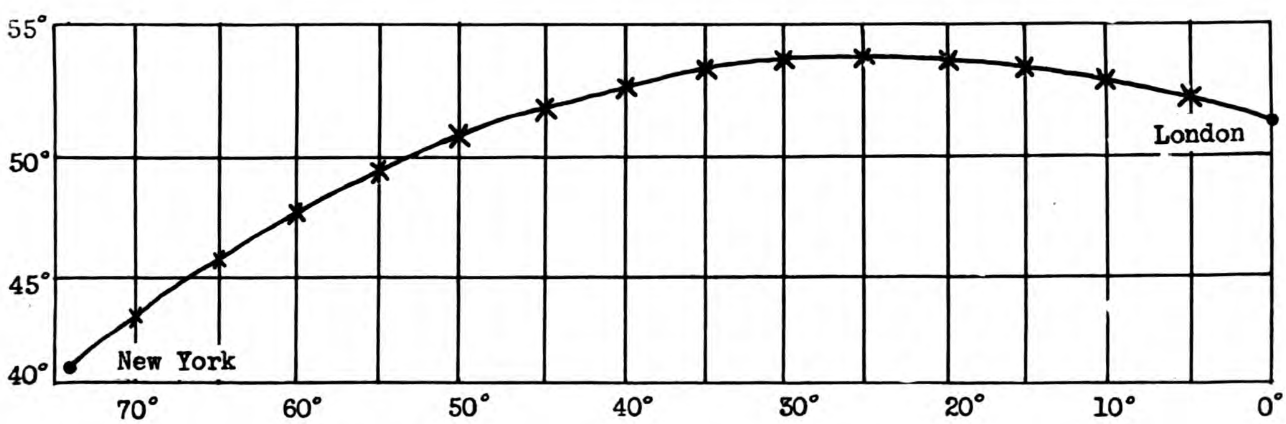
4. Is it customary to fly great circle tracks within 20° of the equator?

   ANS: No. The distance saved does not make it worthwhile.

5. Transfer the great circle track between New York and London, England, from H.O. 1280 to the mercator chart H.O. 1070. Obtain the various mercator tracks and distances along this track and the total distance to London.

   ANS: The great circle track crosses the following meridians of longitude at the indicated latitude:

Leg No.	Meridian	Lat. of Crossing	Leg No.	Meridian	Lat. of Crossing
1	70°	43°-20'	9	30°	53°-35'
2	65	45 -35	10	25	53 -45
3	60	47 -35	11	20	53 -45
4	55	49 -20	12	15	53 -30
5	50	50 -40	13	10	53 -05
6	45	51 -45	14	05	52 -25
7	40	52 -40	15	London	51 -30
8	35	53 -15			



When these co-ordinates are transferred to Mercator chart 1070, the route appears as above.

The tracks and distances for each leg follow:

Leg No.	Mercator Track	Distance	Leg No.	Mercator Track	Distance
1	051°	232	9	085°	180
2	056	256	10	084	180
3	059	240	11	090	179
4	062	225	12	095	179
5	067	210	13	098	180
6	071	200	14	101	185
7	073	194	15	108	194
8	081	182			
			Total Distance		3,016

CLASSROOM PROBLEMS
(Use charts H.O. 1280, V.P. 102 and V.P. 103 or equivalent)

1. Lay down the great circle track from New York to Horta (Fayal), Azores Isls. Does your track agree with that already laid down on the V.P. charts? What is the mercator track and distance for each leg? What is the total distance?

2. Lay down the great circle track from Bermuda to Horta (Fayal). Does your track agree with that already laid down? What is the mercator track and distance for each leg? What is the total distance?

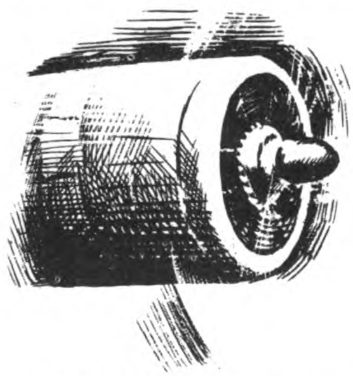
3. The following winds have been forecast between Bermuda and Horta. The cruising airspeed of your plane is 120 knots. (One knot equals 1 nautical mile per hour) How long will it take to make the flight?

(Great Circle Track) FORECAST WINDS Bermuda-Horta

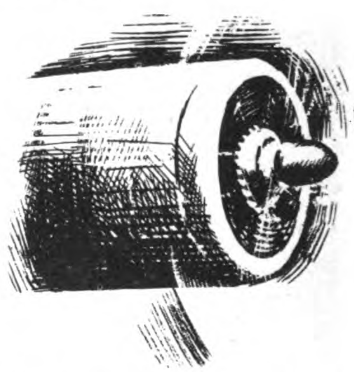
From	To	Track	A.S.	Wind	G.S.	Distance	Time
Bermuda	55° West			290-15			
55° W.	50			290-15			
50	45			315-25			
45	40			230-25			
40	Horta			200-20			
						Total Time:	

AIRCRAFT PERFORMANCE - SPECIFIC FUEL CONSUMPTION

Very low power, high fuel consumption per H. P.



IDEAL CONDITIONS, low fuel consumption per H.P.



Maximum power, high fuel consumption per H.P.

When an internal combustion engine burns 1/2 lb. of gasoline per hour to develop one horsepower throughout the hour, it has a Specific Fuel Consumption of .5

There is a best operating condition with regard to horsepower, R.P.M., fuel-air mixture, and altitude for each type of aircraft engine. Under other operating conditions, the specific fuel consumption is higher.

EXAMPLE PROBLEMS

1. An engine has a specific fuel consumption of .5 when developing 500 HP. How much gas will be burned in one hour?

   ANS: 250 lbs.

2. An engine has a specific fuel consumption of .45 when developing 1,000 H.P. How much gas will be burned on a three hour flight, at that H.P.?

ANS: 1,350 lbs.

CLASSROOM PROBLEMS

1. You are to make a three hour flight in a twin engined plane. 600 H.P. per engine will be developed. The specific fuel consumption is .50 What weight of fuel will be burned?

ANS:______________________________

2. In the above problem, you wish to carry an hour and one-half reserve supply of gas. What weight of gas should be loaded?

ANS:______________________________

3. You are to make a ten hour flight in a four engined plane. 750 H.P. per engine will be developed. The specific fuel consumption is .45 A three hour reserve is to be carried. What weight of fuel must be loaded?

ANS:______________________________

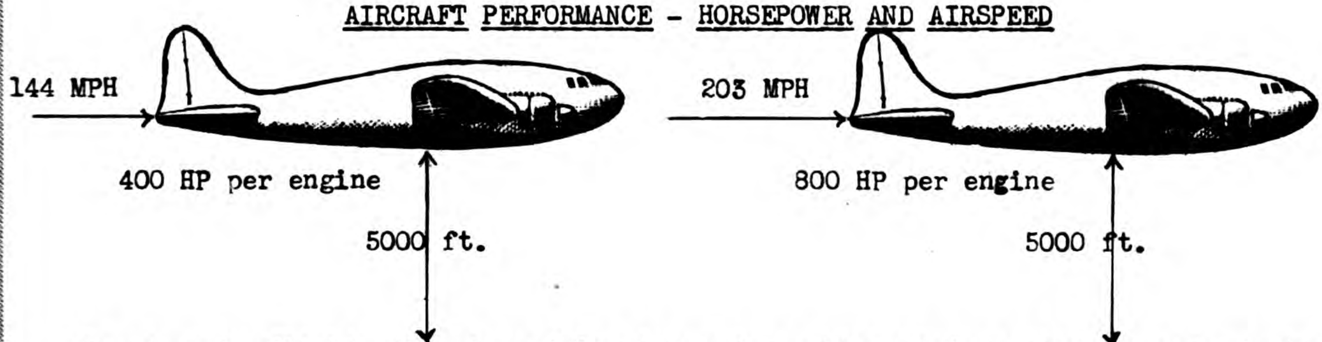
4. In the above problem, how many gallons of gas would have to be loaded if the weight of one gallon of gas is 6 lbs.? How many gallons of gas would have to be loaded if the weight of a gallon of gas were (as it sometimes is) 5.75 lbs.?

ANS:______________________________

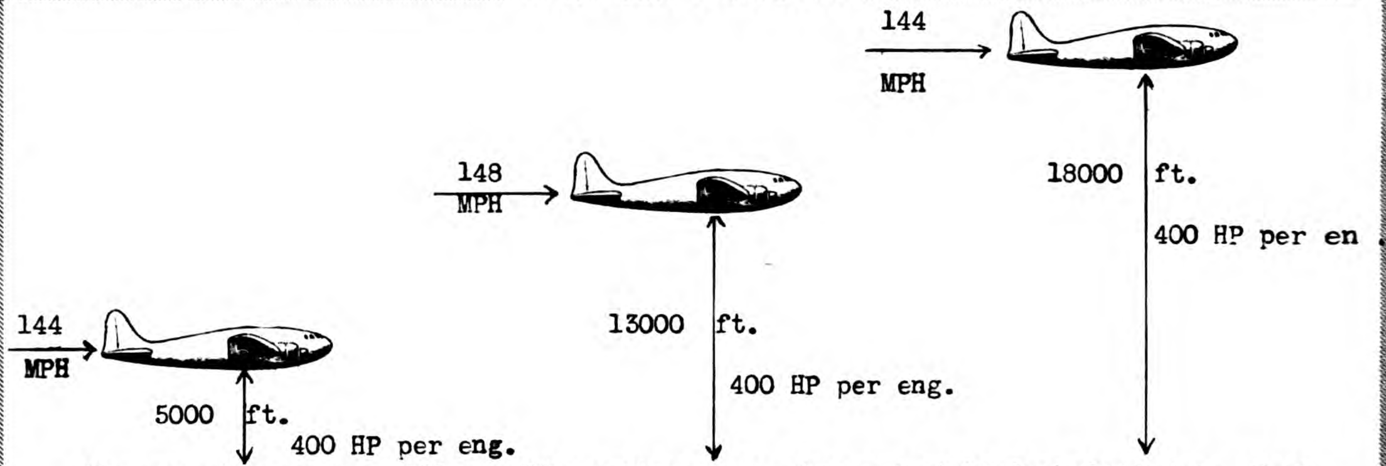
5. Do you believe in finding out just how much a gallon of gas weighs before indicating the number of gallons to be loaded?

ANS:______________________________

<u>AIRCRAFT PERFORMANCE - HORSEPOWER AND AIRSPEED</u>



In straight flight, the aircraft's airspeed is obtained from its power plant alone. At any altitude, greater airspeed may be obtained by increasing the horsepower. Doubling the horsepower <u>does</u> <u>not</u> double the airspeed.



The same horsepower will usually produce more airspeed at higher altitudes. Much depends on aircraft characteristics.

EXAMPLE PROBLEMS

1. How much fuel per mile would be burned under the following conditions? Total H.P. developed, 800. Specific fuel consumption, .50 Airspeed, 150 MPH.

   ANS: 2.66 lbs. per mile with no wind.

2. How much fuel per mile would be burned under the following conditions? Total H.P. developed, 1600. Specific fuel consumption, .50 Airspeed, 200 MPH.

   ANS: 4.00 lbs. per mile with no wind.

CLASSROOM PROBLEMS

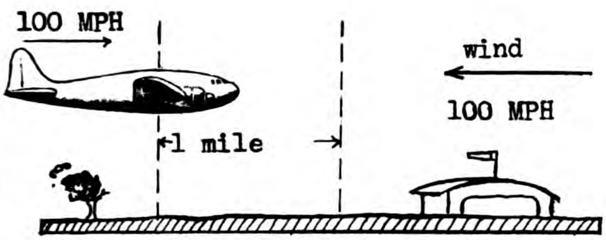
1. The specific fuel consumption is .60 Total H.P. developed is 1,200. Altitude is 5,000 ft. Airspeed is 180 MPH. How much fuel is burned per mile?

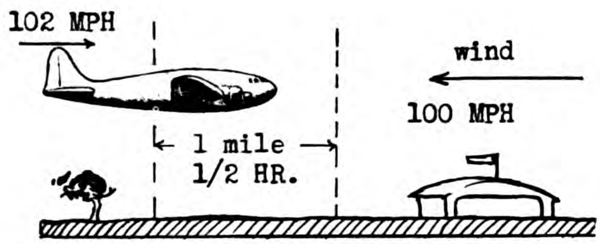
   ANS:____

2. The specific fuel consumption is .60 Total H.P. developed is 1,100. Altitude is 10,000 ft. Airspeed is 180 MPH. How much fuel is burned per mile?

   ANS:____

AIRCRAFT PERFORMANCE - AIRSPEED AND WIND CONDITIONS





If the head wind is equal to the airspeed, the aircraft will use up all the gas aboard and never get to the landing field. If the airspeed is increased to 101 miles per hour, it will reach the field in one hour.

If the airspeed is increased to 102 miles per hour, the plane will reach the field in 1/2 hour. The reduced flight time would, in this case, more than justify the extra fuel burned in developing additional horsepower.

EXAMPLE PROBLEMS

1. An airplane makes the following airspeeds while developing the horsepower shown. It is flying into a hundred MPH head wind. If the specific fuel consumption remains constant at .50, show the fuel consumption per mile over the ground.

	800 H.P.	1,000 H.P.	1,200 H.P.	1,400 H.P.
	145 A.S.	165 A.S.	180 A.S.	190 A.S.
ANS:	8.8 lbs.	7.7 lbs.	7.5 lbs.	7.8 lbs.

2. Is it advisable to increase the horsepower and airspeed when flying into a strong wind?

   ANS: It depends on two factors: How much more fuel will be burned in producing the greater horsepower and airspeed. How long will it take to get out of the headwind area.

CLASSROOM PROBLEMS

1. Your plane makes the following airspeeds while developing the horsepower shown. You are flying into a 30 MPH headwind. At what airspeed will you fly to make the most distance per lb. of fuel? Specific fuel consumption is .50

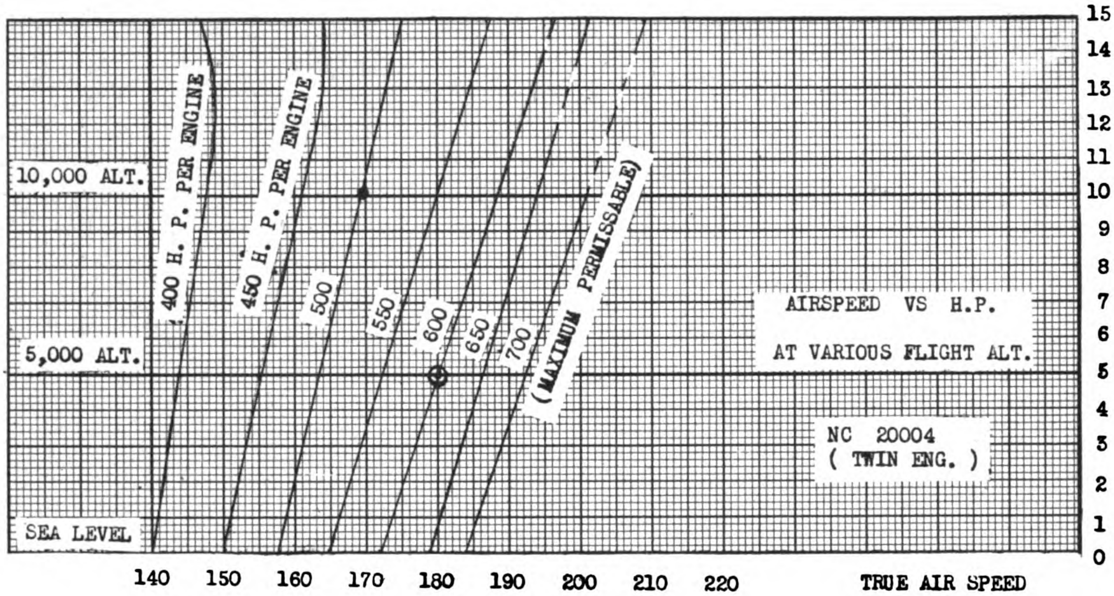
800 H.P.	1,000 H.P.	1,200 H.P.	1,400 H.P.
147 A.S.	170 A.S.	183 A.S.	201 A.S.

   ANS:______________________________

2. If you had a tail wind, how could you make the most distance per lb. of fuel?

   ANS:______________________________

AIRCRAFT PERFORMANCE - AIRCRAFT FLIGHT DATA



The specific performance data for the navigator's plane should be supplied by the manufacturer or the engineering department of his airline. The graph shown above may be used to determine the horsepower required to maintain any airspeed within the cruising limits of one particular type of aircraft.

EXAMPLE PROBLEMS

1. What power per engine must be developed at 5,000 ft. altitude in order to maintain an airspeed of 180 MPH?

   ANS: 600 H.P. per engine.

2. What airspeed will result from developing 500 H.P. per engine at 10,000 ft. altitude?

   ANS: 170 MPH.

3. What weight of fuel will be consumed on a 4 hour flight at 10,000 ft. altitude, if an airspeed of 180 MPH is maintained? Specific fuel consumption is .55

   ANS: 2420 lbs.

CLASSROOM PROBLEMS

1. What horsepower per engine must be developed at 10,000 ft. altitude to maintain an airspeed of 175 MPH?

   ANS:____

2. What airspeed will result from developing 500 H.P. per engine at 8,000 ft.?

   ANS:____.

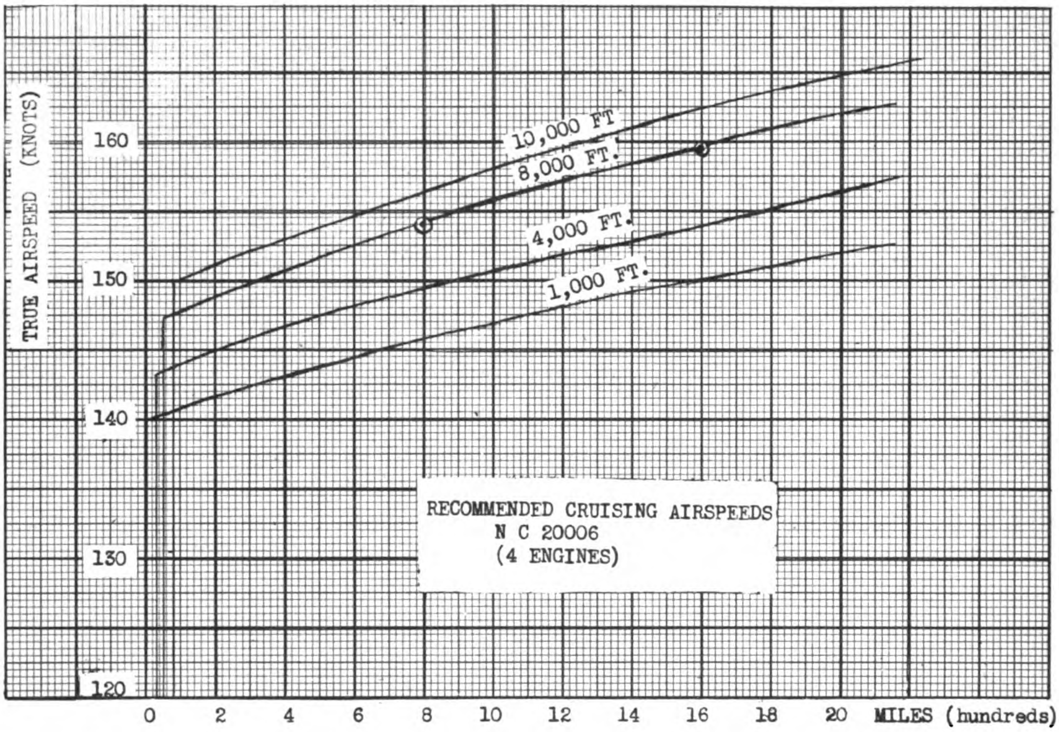
3. You are going to make a 4 hour flight and carry 1-1/2 hours fuel reserve. The flight will be made at 11,000 ft. at an airspeed of 190 MPH. What weight of fuel must be carried? Specific fuel consumption is .55

   ANS:____

4. Do you believe additional fuel should be loaded to allow for the climb to flight altitude?

   ANS:____

AIRCRAFT PERFORMANCE - AIRSPEEDS FOR LONG FLIGHTS



The best cruising airspeeds for various distances out from the base are sometimes presented in the form shown above. This data applies, as in the previous case, to a particular type of aircraft. It also assumes a definite load condition. A lightly loaded plane of the same type would make better speed.

EXAMPLE PROBLEMS

1. The NC 20006 is to make a flight of 2,000 miles at 8,000 ft. What airspeeds should be maintained when 800 and 1,600 miles out?

   ANS: 800 miles out, 154 kts.; 1600 miles out, 159 kts.

2. Why do the airspeeds increase as the flight progresses?

   ANS: The aircraft gets lighter and lighter as fuel is burned, while the horsepower is kept constant.

3. Why does the 10,000 ft. airspeed curve begin 80 miles out?

ANS: It is assumed that the plane will not reach the 10,000 ft. flight altitude until it is that far out.

CLASSROOM PROBLEMS

1. You are to make a 1,600 mile flight at 8,000 ft. The 1,600 miles are divided into four zones of 400 miles each. What average airspeed should be maintained in each zone?

ANS:____

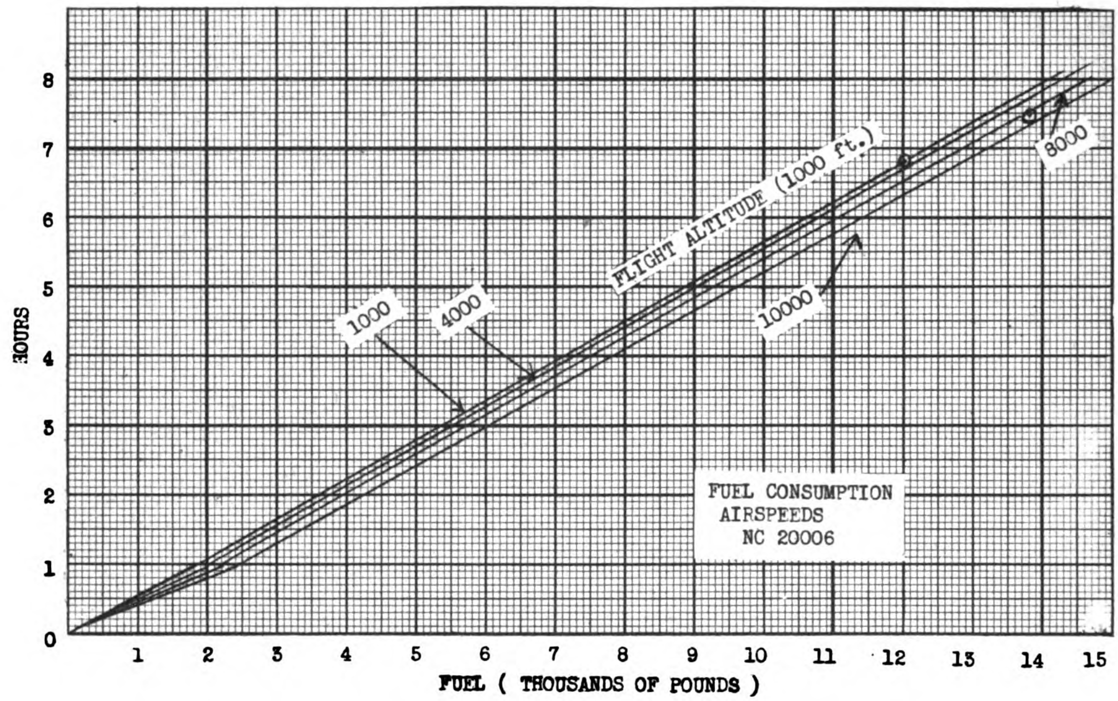
2. How much airspeed could be gained by flying at 8,000 ft. instead of 4,000 ft. when 1,000 miles out?

ANS:____

3. You are planning a flight of 1,000 miles which has been divided into three zones of 300, 400 and 300 miles. What average airspeeds should be used in each zone at each flight altitude shown on the graph above?

ANS:____

AIRCRAFT PERFORMANCE - FUEL CONSUMPTION



Fuel consumption for NC 20006 at various altitudes (and the speeds previously shown) is given on the chart above. The fuel consumption at 1,000 ft. for the first hour is 1,850 lbs. The 10,000 ft. fuel curve shows a consumption for the first hour of 2400 lbs. This is caused by a higher fuel consumption during the climb interval. Thereafter, the spread in fuel consumption values represents the difference in power plant efficiency at the different flight altitudes.

EXAMPLE PROBLEMS

1. How much fuel will be burned on a 7.5 hour flight at 8,000 ft.?

   ANS: 13,800 lbs.

2. How much fuel will be used on a 6.8 hour flight at 1,000 ft.?

   ANS: 12,000 lbs.

3. A flight can be made at 1,000 ft. in 7.7 hours and at 10,000 ft. in 7.4 hours. Which flight is best from a fuel consumption standpoint?

   ANS: The 7.7 hour flight at 1,000 ft.

4. Is this a typical spread in fuel consumption values?

ANS: The fuel consumption spread for different flight altitudes varies with each type of aircraft. For any given type, it also varies with the horsepower used. If lower airspeeds had been used with this same type of plane, a 15 hour flight at low altitude could be shown to be more advantageous from a fuel standpoint than a 14 hour flight at high altitude.

CLASSROOM PROBLEMS

1. How much fuel will be furned on an 8 hour flight at 1,000 ft.?

ANS:____

2. How much fuel will be burned on an 8 hour flight at 10,000 ft.?

ANS:____

3. Do you believe in analyzing the fuel consumption situation as well as the possible flight time prior to specifying the flight altitude for your trips?

ANS:____

4. You are planning a flight from New York to Bermuda (use H.O. chart V.P. 102). According to the flight forecast, there will be a windshift 400 miles out at a frontal condition. The wind at various flight altitudes on each side of the front are set forth below. Show the fuel consumption for the trip at each flight altitude.

ANS:

1,000 ft.

ZONE DIST.	TRACK	WIND	A.S.	G.S.	TIME THRU ZONE	GAS REQUIREMENT
400		320-25				
		230-20				
		TOTALS				

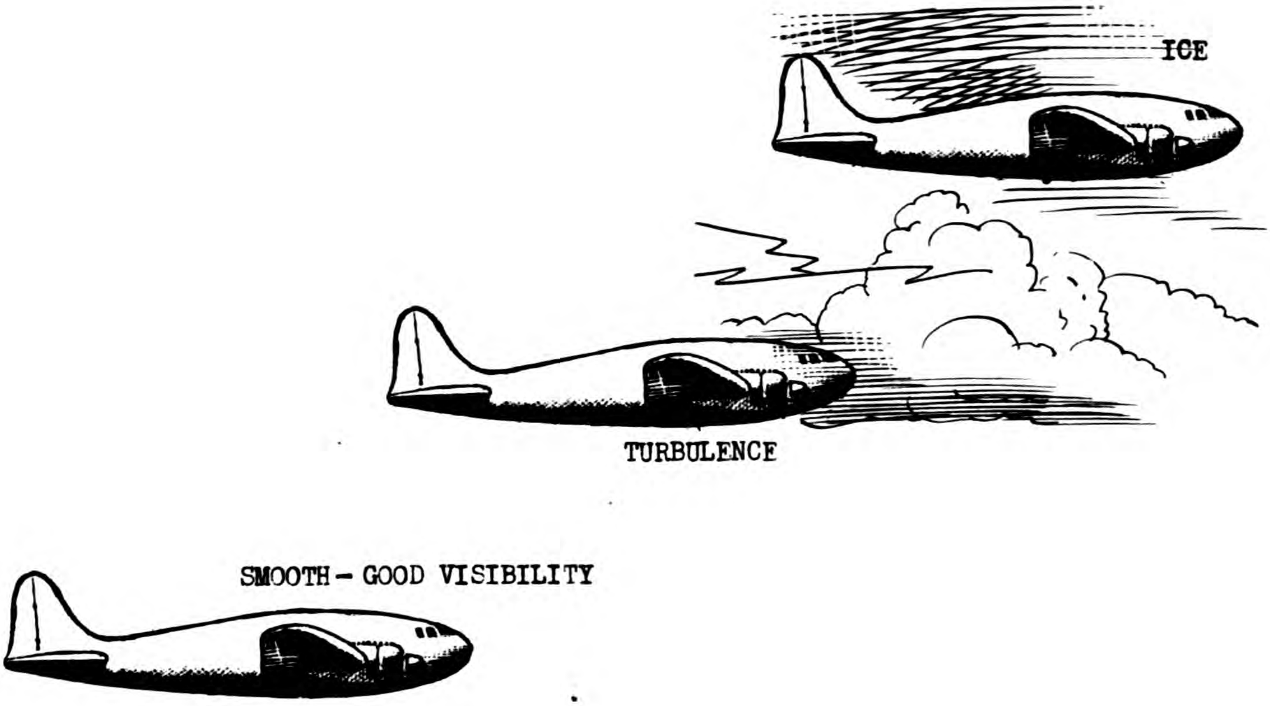
4,000 ft.

ZONE DIST.	TRACK	WIND	A.S.	G.S.	TIME THRU ZONE	GAS REQUIREMENT
		300-35				
		240-30				
		TOTALS				

10,000 ft.

ZONE DIST.	TRACK	WIND	A.S.	G.S.	TIME THRU ZONE	GAS REQUIREMENT
		280-40				
		240-30				
		TOTALS				

SELECTION OF FLIGHT ALTITUDE



Weather conditions <u>may</u> rule out the possibility of using a flight altitude that would be best from the standpoint of time or fuel or both. These conditions are set forth in the FLIGHT FORECAST which contains the predicted winds.

FLIGHT FORECAST - NEW YORK TO BERMUDA

Forecast period: 0000 to 1200 GCT   Scheduled departure: 0600 GCT

A low pressure area centered over western Massachusetts is moving due eastward 15 miles per hour. Mild cold front will be located across track approximately 400 miles from New York.

WEATHER: N.Y. to cold front

Overcast, ceiling 5,000, cloud tops 7,000, upper broken decks, base 10,000, top 14,000 merging with lower clouds at front. Visibility 10 miles or better decreasing to 3 miles at the front in scattered rain showers. Icing level 5,000 at New York, sloping up to 7,000 at front. Light to moderate turbulence at front. Sea fresh.

Wind 1,000 ft. - 320°- 25
4,000 ft. - 300 - 35
10,000 ft. - 280 - 40

WEATHER: Cold front to Bermuda

Broken clouds above 10,000 with visibility unlimited. Sea moderate.

Wind 1,000 ft. - 230°- 20
4,000 ft. - 240 - 30
10,000 ft. - 240 - 30

TERMINAL FORECAST: Bermuda

High scattered clouds becoming broken after 0600 GCT. Visibility unlimited.

ALTERNATE AIRPORT: Norfolk, Va.

Overcast 2,500 becoming broken at 5,000 or better by 0600 GCT. Visibility about 9 miles. Clouds dissipating by 1200 GCT.

EXAMPLE PROBLEMS

1. Can an airplane be flown through moderate turbulence?

   ANS: Yes, but it is uncomfortable.

2. How much turbulence must be expected in a thunderstorm?

   ANS: Enough to seriously damage an airplane.

3. How long could you fly in severe icing conditions?

   ANS: A matter of minutes.

4. Would the ice melt later?

ANS: Sometimes. If the plane can still climb, it might be possible to get above the icing level where ice will slowly evaporate. It might be possible to make a controlled descent into warm air where the ice would melt.

CLASSROOM PROBLEMS

1. Under what conditions would you recommend a change of flight altitude from one to ten thousand feet?

   ANS: ______________________________

2. Do you gain as much time in a descent as you lose in a climb?

   ANS: ______________________________

3. Would it make any difference to you if the winds were forecast for arbitrary mileage zones along the track instead of for certain weather zones?

   ANS: ______________________________

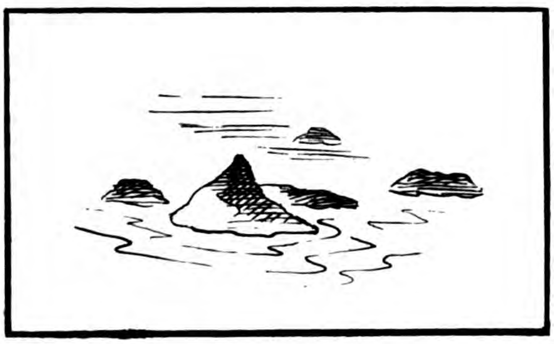
4. Is visibility intended to mean horizontal visibility or the distance a pilot can see vertically downward?

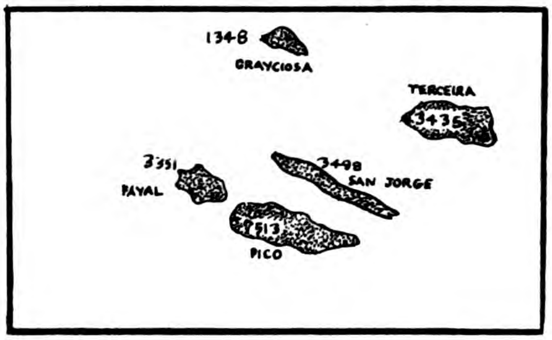
   ANS: ______________________________

5. Is a fresh sea one formed by a new windshift?

   ANS: ______________________________

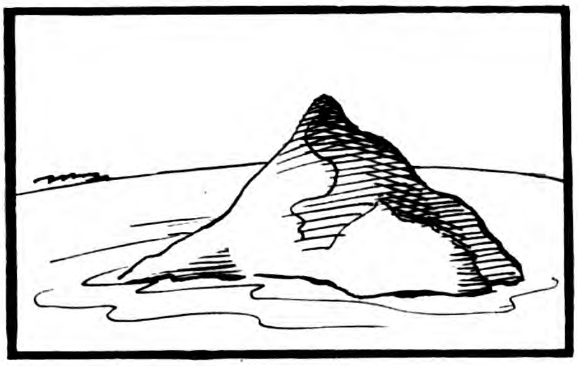
HEIGHTS OF TERRAIN - OCEAN CHARTS
(Use H.O. V.P. 104 or equivalent)

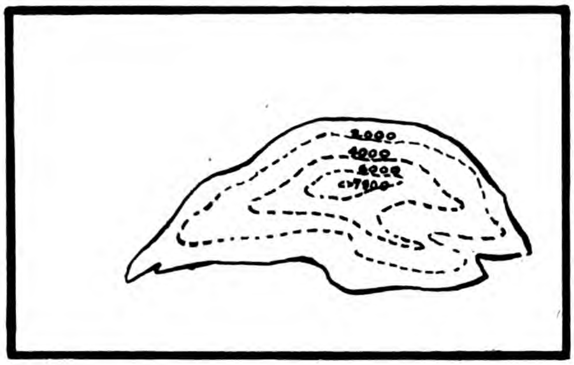




In ocean flying, the navigator has a wider choice of flight altitudes than would normally be the case in cross-country flying. At certain points along the route, however, he must either <u>fly high</u> or deliberately <u>go off track</u> or <u>both</u>.

Note how mountains are shown on his chart. Little detail is given other than the spot at which the highest altitude occurs. This is known as a "spot height".





More detailed charts or maps show lines joining points of equal height. These lines are called "contour lines" and, if they are shown as broken lines, they must be considered approximate only.

The horizontal distance between such lines gives an indication as to the steepness of the mountain.

HEIGHTS OF TERRAIN - CROSS COUNTRY CHARTS
(Use U.S.C.&G.S. Chart #3060-B or equivalent)

This same system of contour and spot height markings is used on the aeronautical strip maps used in this country for cross country flying. In addition, a coloring system is used to emphasize area heights. High spot heights may exist in a colored area.

Our coloring system is not the same as that used by some foreign countries.

Our system of stating heights in feet is not used by countries employing the metric system. Their charts indicate heights in meters. A meter is about 3-1/4 feet.

EXAMPLE PROBLEMS

1. You are in flight and have just passed over the 2,000 ft. contour line at an altitude of 3,000 ft. Is this enough altitude to hold until near the 3,000 ft. contour line?

   ANS: Definitely not. The land between the two and three thousand foot contour lines may reach up to 2,999 ft. and trees may extend up another 150 ft.

2. At what minimum safe altitude could you cross the 5,000 ft. contour headed toward the 7,000 ft. contour?

   ANS: 7,500 ft. would be the lowest safe altitude if there were no intervening spot heights above 7,000 ft.

3. Northeast of Great Falls, Montana, (see Glacier Park) there is an area bounded by a 5,000 ft. contour line. What altitudes are indicated by the color tint within that area? What is the highest point within that area?

ANS: The color tint shows that the altitudes within the 5,000 ft. contour may rise to 7,000 ft. The highest altitude shown within that area is that of a mountain 6,906 ft. high.

CLASSROOM PROBLEMS
(Use U.S.C.& G.S. chart #3060-B or equivalent)

1. What height of terrain is indicated by the color tint between Chicago and Kansas City?

ANS:____

2. Should you fly directly from Memphis, Tenn., to Wichita, Kan., at an altitude of 3,000 ft.?

ANS:____

3. According to the color tints, what would be the minimum safe altitude at which you might approach Amarillo, Texas, from Oklahoma City, Okla.?

ANS:____

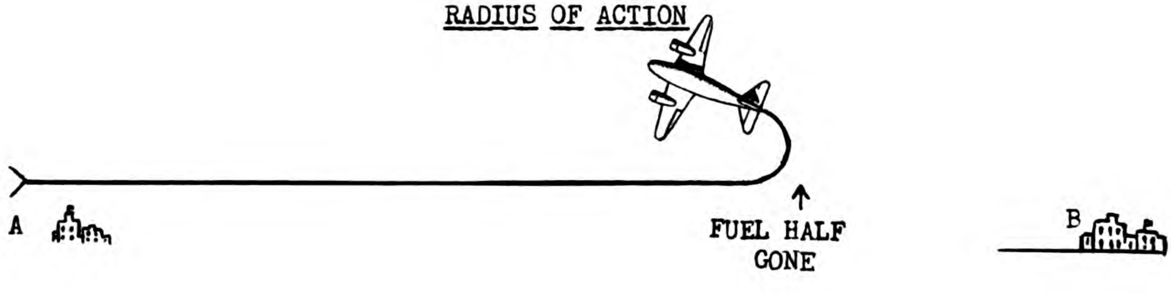
4. Why does the airway from Denver to Salt Lake City curve around to the northward instead of going directly into Salt Lake City?

ANS:____

5. At what altitude would you have to fly if you went direct to Billings, Montana, from Cheyenne, Wyoming?

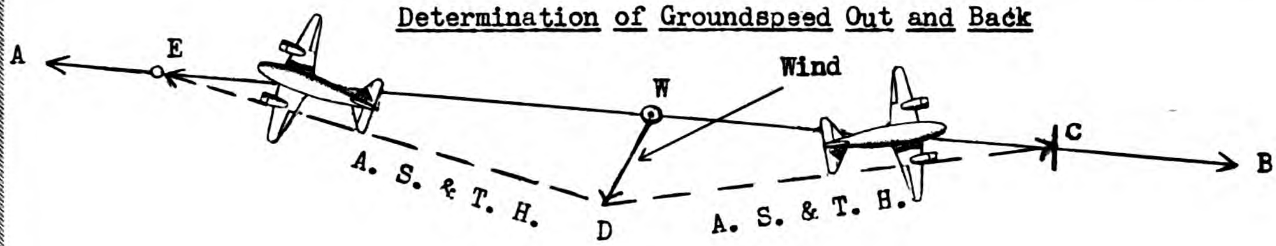
ANS:____

RADIUS OF ACTION



If you have been flying with a tail wind and have used up half the gas load, you can never expect to get back to your starting point unless the wind changes.

Determination of Groundspeed Out and Back



It is of the utmost importance to determine how long the plane may proceed toward it destination and still get back, if necessary. Either the distance out along the track may be determined or the time to the point of no return may be determined. In either case, the groundspeed out and the groundspeed coming back must be known.

The groundspeed out from "A" toward "B" is represented by the line W-C. The groundspeed back is represented by the line W-E.

In this diagram a scale of 40 miles to an inch has been used but scaling the lengths of the groundspeed lines tells nothing more than the fact that 90 MPH will be made going out and 110 MPH coming back.

Derivation of Radius of Action Formulas

Let the following symbols represent the following values:

T Total allowable flight time (possible flight time less reserve)

t_1 Time out to point of no return

t_2 Time back from point of no return

r_1 Rate of leaving A for B (G.S. out)

r_2 Rate of returning to A (G.S. back)

R Radius of action (distance to point of no return)

$$T = t_1 + t_2$$

$$t_1 = \frac{R}{r_1}$$

$$t_2 = \frac{R}{r_2}$$

$$T = \frac{R}{r_1} + \frac{R}{r_2}$$

$$T = \frac{Rr_2 + Rr_1}{r_1 r_2}$$

$$T = \frac{R(r_1 + r_2)}{r_1 r_2}$$

$$R = \frac{Tr_1 r_2}{r_1 + r_2} \quad (1)$$

but $R = t_1 r_1$

therefore $t_1 = \dfrac{Tr_2}{r_1 + r_2}$ (2)

Formula #1 must be committed to memory. By its use the distance out to the point of no return may be reckoned and, if the time out to the point is desired, it may be obtained by dividing this distance by the groundspeed out along the track.

EXAMPLE PROBLEMS

1. The groundspeed out is 150 miles per hour and the groundspeed back is 120. Total allowable flight time (not counting reserve) is 6 hours. What is the distance to the point of no return?

   ANS: $R = \frac{Tr_1r_2}{r_1 + r_2} = \frac{6 \times 150 \times 120}{150 + 120} = 400$ miles

2. In the above problem, how long may the plane be flown towards its destination before turning back?

   ANS: 400 divided by 150 or 2.66 hours.

3. Is the term radius of action applicable to the distance back as well as to the distance out?

   ANS: Certainly. Both distances are the same.

CLASSROOM PROBLEMS

1. You have loaded a 10 hour supply of gas which includes a 2 hour reserve. With no wind, how long could you proceed toward your destination before turning back?

   ANS:______________________________

2. If you were calculating the flight time to the point of no return, would you consider the effect of all the winds enroute to final destination or those extending approximately half way out?

   ANS:______________________________

3. ou have loaded a 7.5 hour supply of gas for a 5.5 hour flight. The track is 110°; cruising airspeed is 150 MPH; wind in first half of flight is North 40 MPH. In the last half of the flight, the wind is 080°-40 MPH. What is the flight time to the point of no return?

   ANS:______________________________

4. You receive the following Bermuda - New York forecast at Bermuda. Analyze the possible flight times, the fuel consumption, select the most advantageous flight altitude and complete the flight plan. (Use H.O. chart #VP 102 or the equivalent.)

FLIGHT FORECAST - BERMUDA TO NEW YORK

Forecast period: 0600 to 1800 GCT   Scheduled departure: 1000 GCT

A high pressure area of 1,018 millibars centered on track approximately 350 miles out of Bermuda, nearly stationary. No fronts on route.

WEATHER ZONE 1 (first 250 miles) lower broken clouds, base 3,000, tops 4,500, visibility 15 miles, freezing level 10,000 feet.

Winds 1,000 ft. - 060 - 16
4,000 ft. - 080 - 16
10,000 ft. - 090 - 14

WEATHER ZONE 2 (next 200 miles) no low clouds, high scattered clouds, base 8,000, tops 12,000, visibility 15 miles, freezing level 10,000 ft.

Winds 1,000 ft. - 300 - 5
4,000 ft. - 350 - 12
10,000 ft. - 350 - 14

WEATHER ZONE 3 (last 220 miles) high overcast, base 8,000, tops 14,000, visibility 12 miles, freezing level 8,000 ft.

Winds 1,000 ft. - 230 - 14
4,000 ft. - 270 - 18
10,000 ft. - 300 - 22

TERMINAL WEATHER: Bermuda low scattered clouds at 3,000, temp. 68, Bar. 1013.2, surface wind East 12 MPH. Sea slight, vis. 15 miles

New York high overcast at 8,000 ft., temp. 64, Bar. 1013.3, surface wind SW 10 MPH. Sea smooth, vis. 8 miles reduced by smoke.

ALTERNATE: Bridgeport, Conn. Same as New York.

FLIGHT ANALYSIS

1,000 ft.

ZONE DIST.	TRACK	WIND	A.S.	G.S.	TIME THRU ZONE	GAS REQUIREMENT
250						
200						
220						
		TOTALS				

4,000 ft.

ZONE DIST.	TRACK	WIND	A.S.	G.S.	TIME THRU ZONE	GAS REQUIREMENT
		TOTALS				

10,000 ft.

ZONE DIST.	TRACK	WIND	A.S.	G.S.	TIME THRU ZONE	GAS REQUIREMENT
		TOTALS				

FLIGHT PLAN

ALTITUDE

			ACCUMULATIVE		
END OF ZONE	G.S.	TIME THRU ZONE	TIME	FUEL	GAS ABOARD 12,000
0					
250					
450					
670					
		TOTALS			

Gas Reserve________________

Gas weight per gallon: 6.00 lbs.

Alternate: Bridgeport

Time to point of no return _________
(2 hrs. reserve)

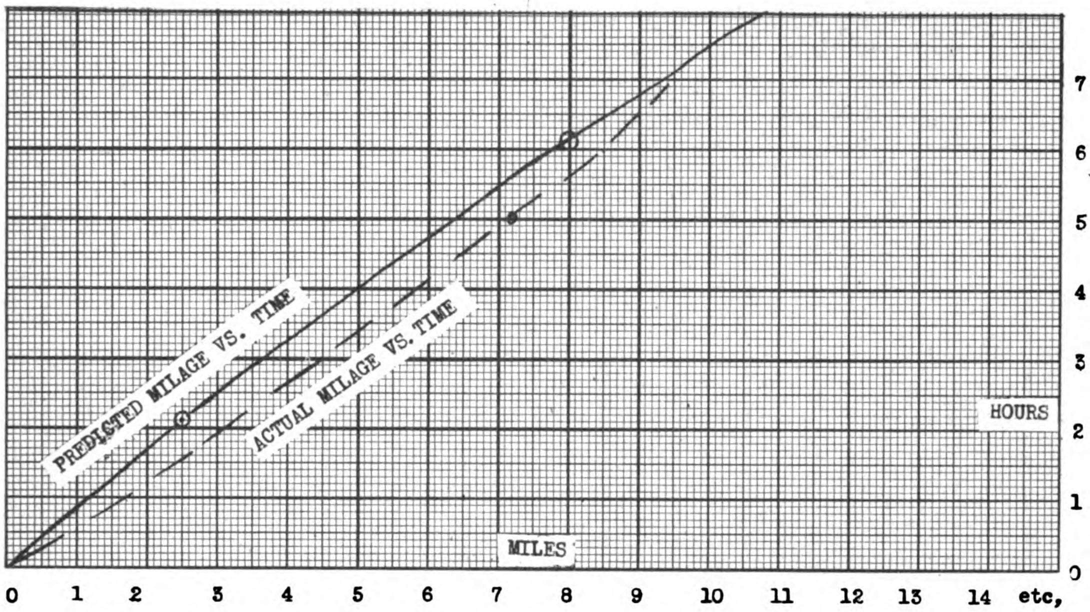
Capt. Signature________________ Nav. Signature________________

Flight Plan Notes: The plane has been loaded with 12,000 lbs. of gas. The gas aboard at the end of each zone is obtained by subtracting the gas used up to that point from the total aboard at the start.

Before the point of no return can be determined, it will be necessary to enter the fuel consumption curves to find out how long the plane can fly before using up 12,000 lbs. This time, less the two hour reserve, is to be used in the point of no return formulas.

FLIGHT CONTROL
(Use of flight plan data)

MILES vs. TIME



Immediately after the commencement of any long flight, the predicted performance of the plane is plotted on a graph. This is done so that the actual performance may be plotted and compared with it to show up any favorable or unfavorable trends.

The solid line represents the predicted miles made good for any number of hours out from the base. This data is obtained from the flight plan. The dotted line represents the actual miles made good for various times out from the base. This information is supplied by the navigator during the flight. The trend is unfavorable though the plane is ahead of schedule.

EXAMPLE PROBLEMS

1. According to the graph above, what was the predicted flight time for the first zone of 250 miles?

   ANS: 2.1 hours.

2. What was the predicted flight time for the first 800 miles?

   ANS: 6.1 hours.

3. How many miles has been made good at the end of 5 hours?

   ANS: 720 miles.

CLASSROOM PROBLEMS

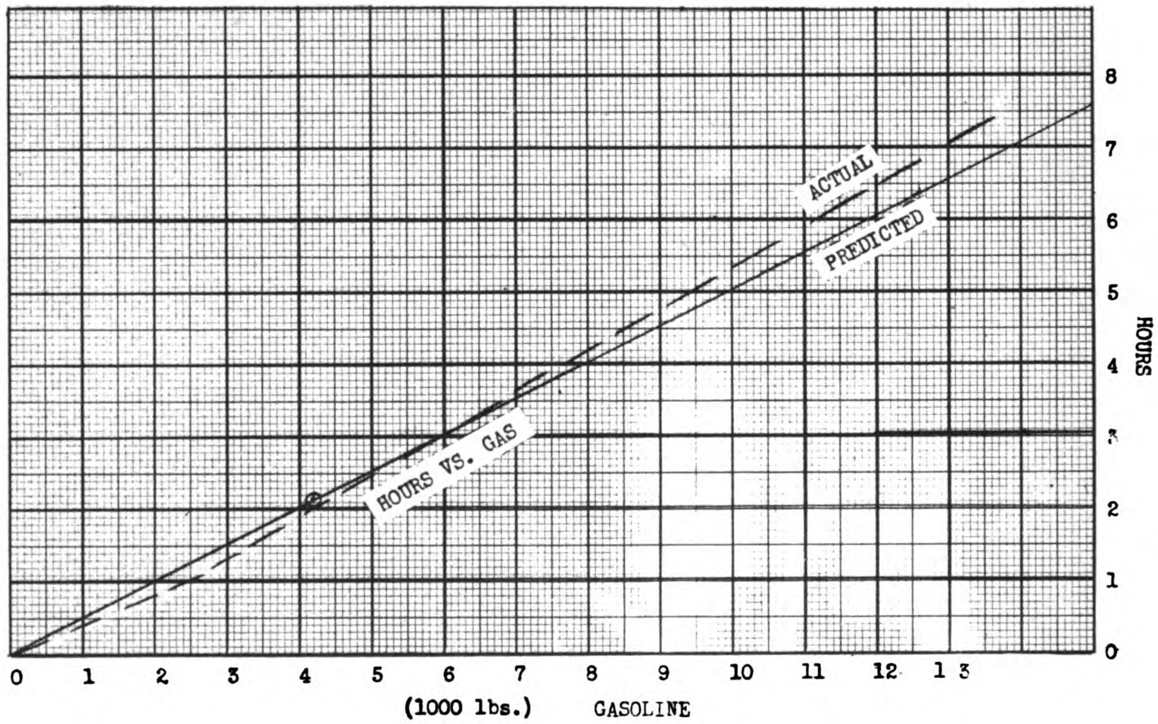
1. How many miles ahead or behind schedule was the plane at the end of the first, second, third and fifth hours?

   ANS:____

2. Approximately how far ahead or behind schedule will the plane be after having flown 7-1/2 hours?

   ANS:____

GAS vs. TIME



In a similar manner, the predicted gasoline consumption is plotted against the predicted flight time in order that any irregular trend in the fuel consumption may be noted at a glance. The actual consumption (shown by the dotted line) is furnished every hour by the flight engineer.

EXAMPLE PROBLEMS

1. According to the graph above, how much gas should have been burned in the 2.1 hour interval after take-off?

   ANS: 4,200 lbs.

2. How much fuel should have been burned in the first 6.1 hours?

   ANS: 12,000 lbs.

CLASSROOM PROBLEMS

1. How much gas was actually burned at the end of 6 hours?

   ANS:______________________________

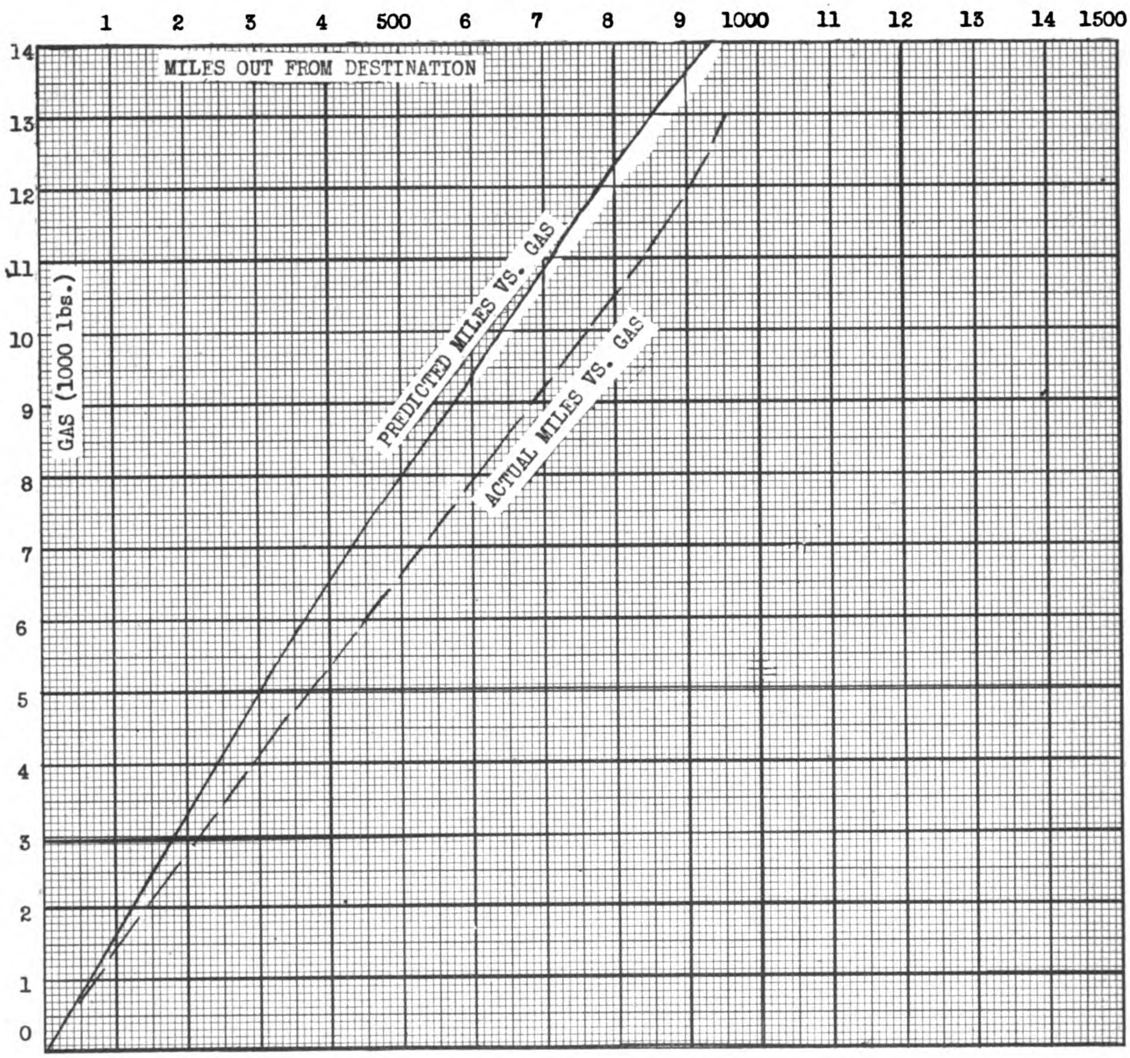
2. Is the total consumption higher or lower than expected at the end of 4 hours?

   ANS:______________________________

3. Do you think the trend in the actual mileage plot will be offset by the trend in the actual gas consumption plot?

   ANS:______________________________

MILES vs. GAS



The real answer to the question of overall performance is found in the flight control graph illustrated above. The gas consumption may be higher than normal or the groundspeed may be less than expected. The real problem is this: "Is the gas consumption per mile above or below that predicted for the flight"?

The accumulated zone distances are shown plotted against the accumulated consumption as set forth in the flight plan. The actual mileage, when plotted (as on the dotted line) against the actual consumption shows whether or not the flight is progressing satisfactorily.

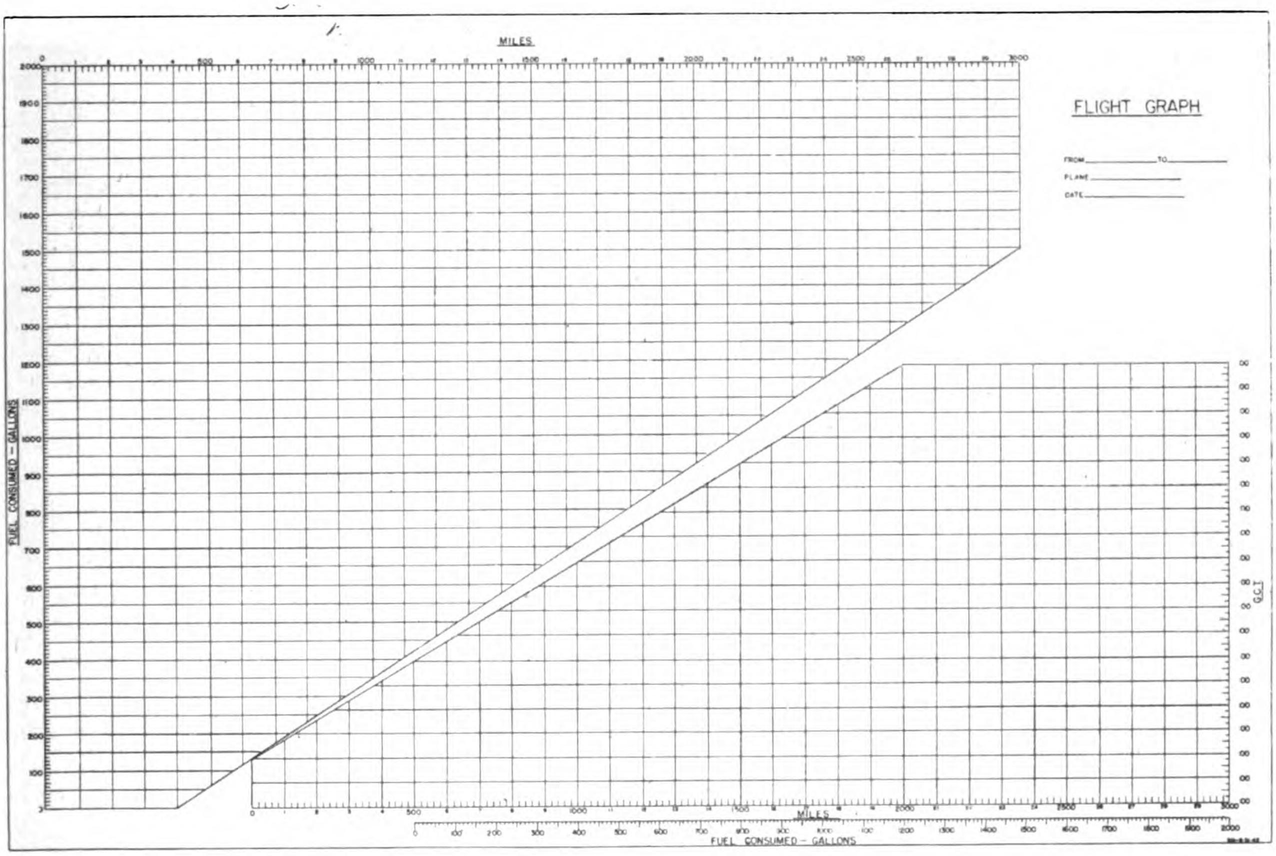
HOWGOZIT SHEET

The flight control data is generally plotted on a single sheet known as the "HOWGOZIT" sheet. Gasoline data is plotted in gallons rather than in pounds because fuel flow meters are usually calibrated in gallons.

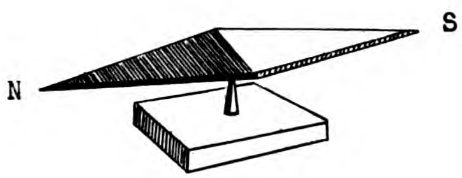
CLASSROOM PROBLEM

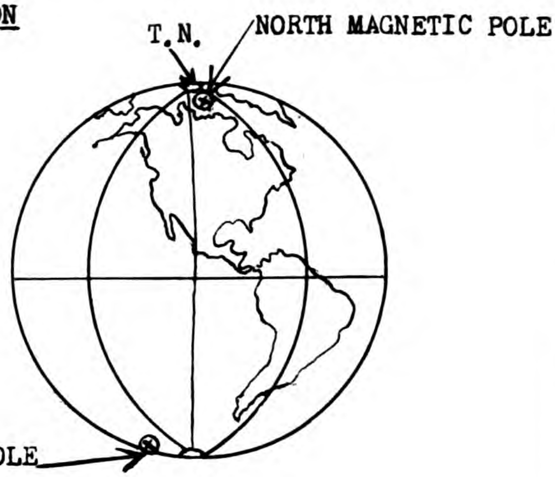
1. Use the data contained in the last flight plan and plot the following three performance curves on the accompanying HOWGOZIT sheet.

   Time vs. Miles
   Time vs. Gas Consumption
   Miles vs. Gas Consumption



COMPASS VARIATION

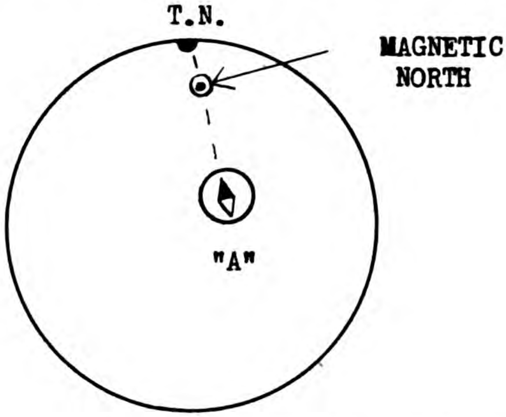


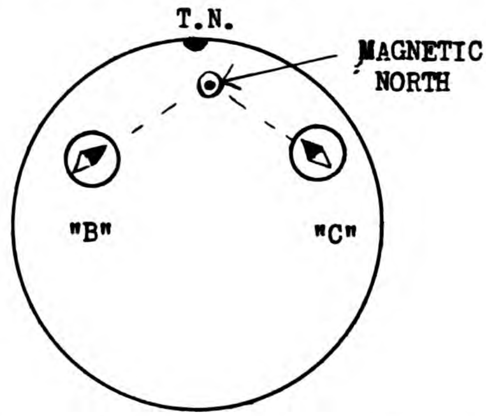


A compass is a magnet mounted so as to swing horizontally.

The magnetic mass toward which the north seeking end normally points is thought to be an ore deposit buried far below the earth's surface, north of Hudson Bay, Canada.

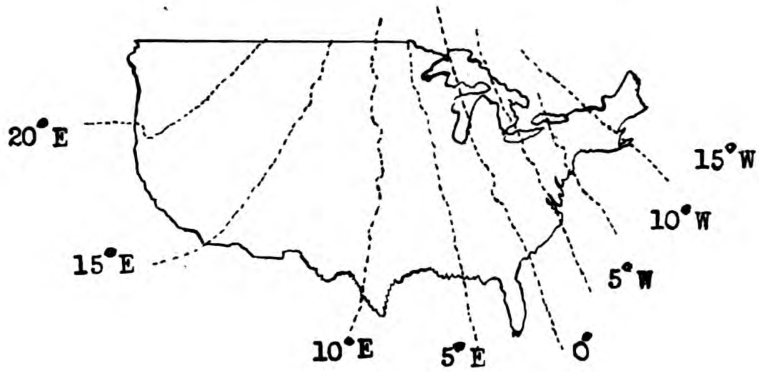
The location of this magnetic ore mass is known as the MAGNETIC NORTH POLE. The magnetic north pole and the true north pole are hundreds of miles apart.





When the magnetic north pole and the true north pole are in line with each other (left diagram above), the compass at point "A" will point to magnetic north and true north as well.

Elsewhere on the earth, it may still point to magnetic north but in so doing it will point somewhat east or west of true north. See "B" and "C" above.



The angular difference between true north and the north shown by a magnetic compass is called VARIATION. If the magnetic needle points west of true north, the variation is called west. If the needle points east of true north, the variation is called east. Lines joining points on the earth where variation is identical are known as lines of equal variation or ISOGONIC LINES.

These lines are always printed on the navigator's charts so that allowance may be made for the difference between true directions and magnetic directions

EXAMPLE PROBLEMS
(Use U.S.C.& G.S. chart #3060-B)

1. You are at Pensacola, Fla. There is nothing around the compass to prevent its functioning normally. Will the north end of the needle point true north?

   ANS: No. It will point 5° east of true north.

2. Where would the north end of the needle point at Boston, Mass.?

   ANS: It would point 15° west of true north.

3. Where would the north end of the needle point if the compass were taken to San Francisco?

   ANS: It would point 18° east of true north.

CLASSROOM PROBLEMS

1. What variation exists at San Antonio, Texas? Where would the north end of a magnetic needle point?

   ANS:____

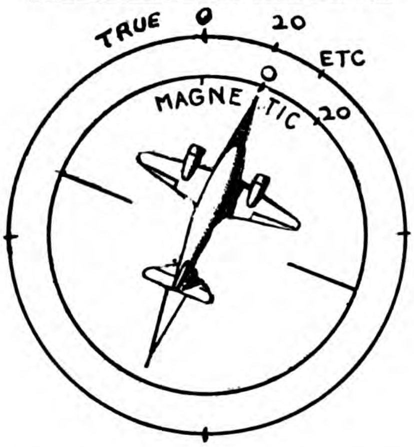
2. What is the variation at Knoxville, Tenn.? Does the north end of the magnetic needle point true north at this city?

   ANS:____

3. In what true direction does the north end of a magnetic needle point at Pittsburgh, Pa.?

ANS: ____________________

APPLICATION OF VARIATION



Two concentric roses are shown above. The outer rose shows true directions and the inner rose shows magnetic directions.

Note that the north end of the magnetic needle points 20 degrees east of true north, showing that it is located at a place where the variation is 20 degrees east.

The plane in the center is headed north according to the magnetic compass which the pilot sees in front of him. It is not headed true north because the north end of the needle points 20 degrees east of true north.

The plane is actually headed 20° true even though the magnetic compass shows it to be headed north.

EXAMPLE PROBLEMS

1. From the diagram above, name the true direction in which the plane would be headed if it were headed in a magnetic direction of 90°.

   ANS: 110°.

2. In the same diagram, name the true direction in which the plane would be headed if it were headed in a magnetic direction of 180°.

   ANS: 200°

3. In the same diagram, name the true direction in which the plane would be headed if it were headed a magnetic direction of 270°.

   ANS: 290°.

4. If a navigator were in flight where the variation was 20° E., would the true heading always be 20° greater than the magnetic heading?

ANS: Certainly, unless the plane happened to be maintaining a magnetic heading between 340° and north. In this case, the addition of the 20° E. variation would give a true heading of 360° or more. A heading of 365° is really 005° after subtracting 360°. North is usually called 000° and not 360°.

5. You wish to maintain a true heading of 220°. The variation is 30° E. What magnetic heading must be steered?

ANS: 190°. Note that the true heading is greater than the magnetic heading as before. However, the true heading was given in this problem and the magnetic heading had to be found.

CLASSROOM PROBLEMS

1. You are steering 300° magnetic where the variation is 40° E. What true heading are you maintaining?

ANS: ____________________

2. You are steering a magnetic heading of 350° where the variation is 30° E. What is the true heading of the plane?

ANS: ____________________

3. You have been steering 120° magnetic through an area where the variation changed from 20° to 24° E. What average true heading did you maintain?

ANS: ____________________

4. Because of wind, you have to maintain a true heading of 100° to keep on track. Reference to your chart shows that the variation is 10° E. If nothing else acts to disturb the compass, what magnetic heading must be maintained?

ANS: ____________________

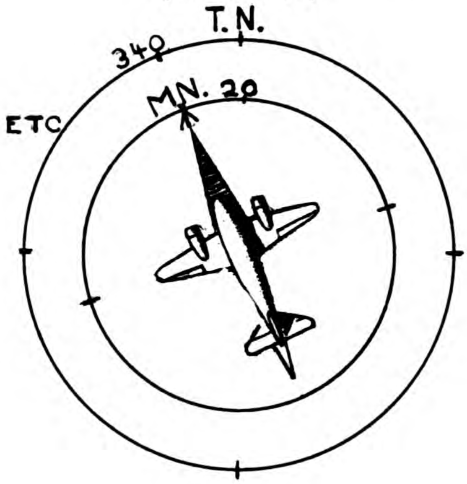
5. The desired true heading is 200° and the variation is 10° E. What magnetic heading must be steered?

ANS: ____________________

6. You wish to maintain a true heading of 005° where the variation is 10° E. What will the magnetic heading be?

ANS: ____________________

APPLICATION OF VARIATION
(Continued)



In this diagram, the outer rose is true and the inner rose is magnetic, as was the case in the previous diagram. The north end of the magnetic needle, however, points 20 degrees west of true north.

The plane in the center is headed north according to the magnetic compass seen by the pilot in front of him but, becuase the needle points 20 degrees west of true north, the plane is actually headed 340° true.

EXAMPLE PROBLEMS

1. From the diagram above, name the true direction in which the plane would be headed if the plane were headed 90° magnetic.

   ANS: 70° true.

2. From the same diagram, name the true direction in which the plane would be headed if the pilot were steering 180° magnetic.

   ANS: 160° true.

3. Using the same diagram, name the true direction in which the plane would be headed if the pilot were steering 270° magnetic.

   ANS: 250° true.

4. If the plane is located where the variation is 20° W., will the true heading always be 20° less than that shown by the magnetic compass?

   ANS: Yes, unless the plane is headed between 20° and north in which case the subtraction of 20° from the magnetic heading will result in a negative number. In such cases 360° is added to the magnetic heading before subtraction is performed.

5. You wish to maintain a true heading of 80°. The variation is 12° W. What must the magnetic heading be?

ANS: 92°.

CLASSROOM PROBLEMS

1. You are headed 150° magnetic where the variation is 15° W. What is the true heading of the plane?

ANS: ____________________

2. You are steering 133° magnetic where the variation is 17° W. What true heading is being maintained?

ANS: ____________________

3. You have been steering 010° in an area where the variation changed from 21° W. to 25° W. What has your average true heading been?

ANS: ____________________

4. Because of wind you must maintain a <u>true heading</u> of 025° to keep on track. The variation is 25° W. What magnetic heading must be steered?

ANS: ____________________

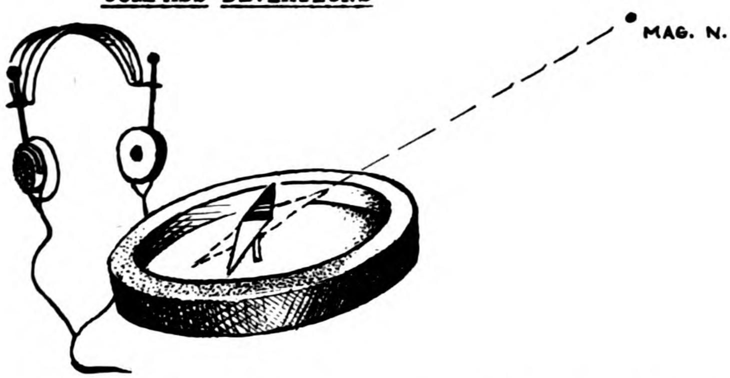
5. You wish to maintain a true heading of 163°. The variation is 3° W. What magnetic heading must be maintained?

ANS: ____________________

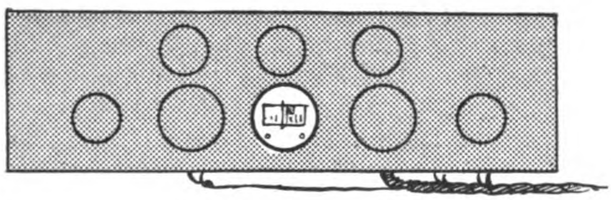
6. You wish to maintain a true heading of 300° through an area where the average variation is 18° W. What magnetic heading must be steered?

ANS: ____________________

COMPASS DEVIATIONS

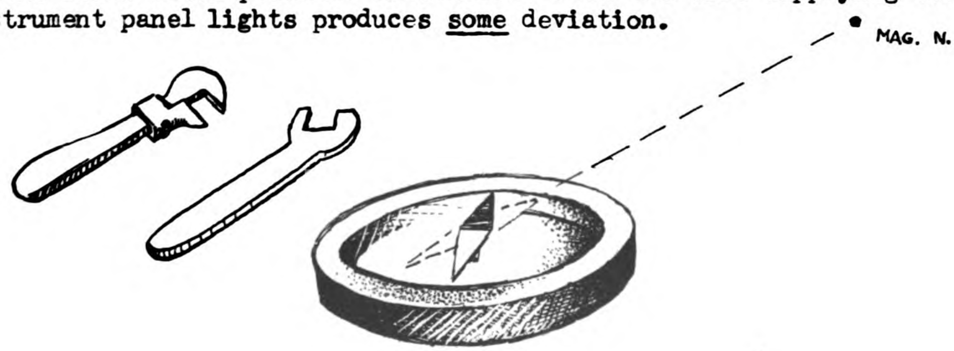


A magnetic compass needle can be made to <u>deviate</u> from its normal position if a local magnetic field is created. Electrical apparatus such as head-phones, light meters, etc., can easily produce a DEVIATION of 20° or more. Such apparatus should always be kept <u>well away from magnetic compasses</u>.

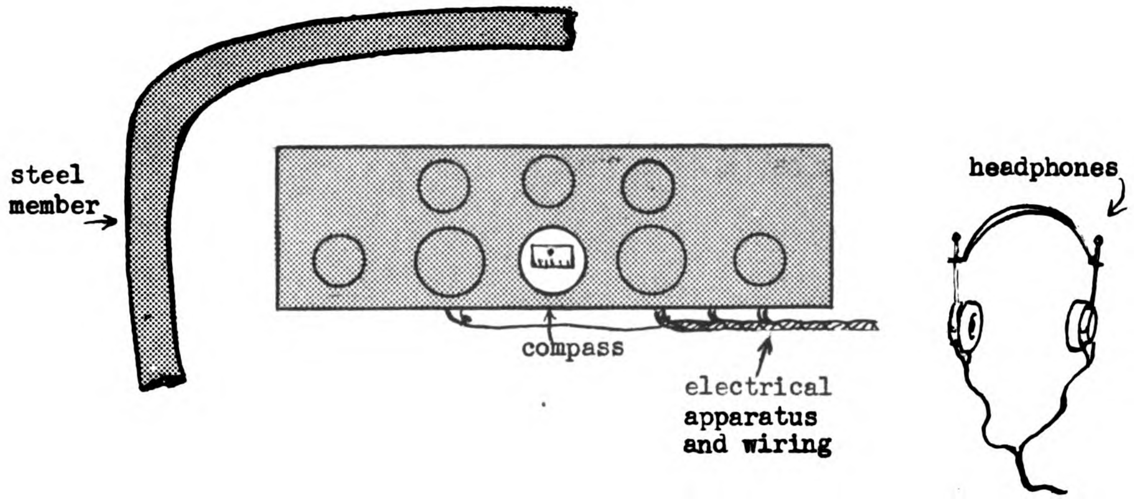


electric panel wires

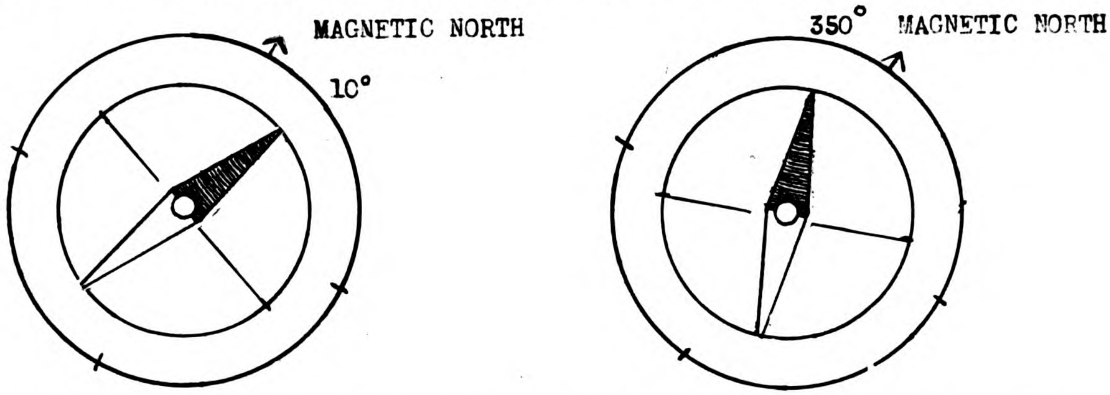
A magnetic field also surrounds the <u>wiring</u> leading to electrical instruments and this magnetic field often produces deviation. Even the wire supplying current to the instrument panel lights produces <u>some</u> deviation.



Not only electrical wiring and instruments produce deviation; any fair sized piece of <u>iron</u> or <u>steel</u> near the compass produces deviation. Mechanics' tools, iron or steel structural members of the aircraft, etc., are examples of this.



These deviation producing objects may neutralize each others effect but more often than not the net result is the creation of a certain amount of deviation. This deviation is not necessarily the same on all magnetic headings.



After the magnetic heading has been determined by application of the variation for the locality, it becomes necessary to make a <u>further</u> correction because deviation prevents the magnetic compass from pointing out correct magnetic directions.

East deviation exists when the north end of the compass needle points east of magnetic north as in "A".

West deviation exists when the north end of the compass needle points west of magnetic north as in "B".

EXAMPLE PROBLEMS

1. The eviation is 10° East. How much and in what direction is the magnetic compass needle deflected from its normal position?

   ANS: The compass needle points 10° east of magnetic north.

2. After applying variation to the desired true heading, the magnetic heading is found to be 100°. The deviation is 10° East. What must the pilot steer by the compass?

   ANS: Since the deviation is 10° East, the pilot would have to <u>steer 090° by compass</u> to head 100° magnetic.

3. The deviation is 5° East. What compass heading must be maintained to keep the plane headed 300° magnetic?

   ANS: 295°.

4. The desired true heading is 070°. The variation is 20° W. and the deviation is 5° East. What compass heading must be maintained?

   ANS: 085°.

CLASSROOM PROBLEMS

1. The magnetic heading desired is 175°. The deviation is 4° E. What compass heading must be steered?

   ANS:____

2. The magnetic heading desired is 175°. The deviation is 4° W. What compass heading must be steered?

   ANS:____

3. The desired track is 100°. The true heading to maintain is 100°. The variation is 5° W. What magnetic heading must be maintained? The deviation is 0° E. What compass heading must be steered?

   ANS:____

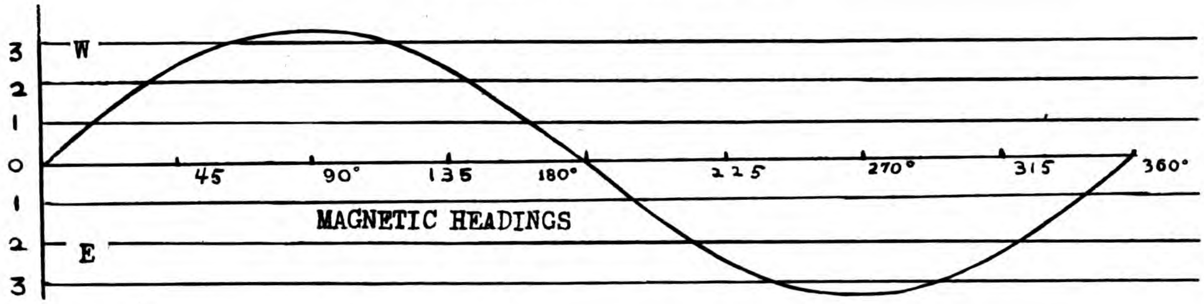
4. The magnetic heading to maintain is 355°. The deviation is 6°W. What compass heading must be steered?

   ANS:____

5. The magnetic heading to maintain is 035°. The deviation is 2° E. What compass heading must be steered?

   ANS:____

COMPASS DEVIATION GRAPHS



The deviation existing in a compass is often shown on a graph such as that above. East deviations are shown below the center horizontal line and west above.

First apply the variation to the true heading and obtain the magnetic heading. Then enter the graph with the magnetic heading and apply the deviation shown for that heading.

EXAMPLE PROBLEMS

1. The true heading is to be 190°. Variation is 10° E. According to the graph above, what must the compass heading be?

   ANS: 180°. There is no deviation on this heading.

2. The magnetic heading to be maintained is 90°. What is the deviation for this heading and what must be steered by compass?

   ANS: Deviation on 90° magnetic is 3-1/2° W. Steer 93° or 94° by compass.

3. The magnetic heading is to be 200°. What is the deviation on this heading and what must be steered by compass?

   ANS: The deviation on 200° is 2° E. Steer 198° by compass.

CLASSROOM PROBLEMS

(Use U.S.C. & G.S. chart #3060-B or equivalent and the above deviation graph)

1. You wish to leave Boston on a true heading of 090°. What magnetic heading will be maintained? What compass heading will be steered?

   ANS: ____________________

2. You wish to leave San Francisco on a true heading of 250°. What magnetic heading will be maintained? What compass heading will be steered?

   ANS: ____________________

3. You wish to leave New Orleans on a true heading of 180°. What magnetic heading will be maintained? What compass heading will be steered?

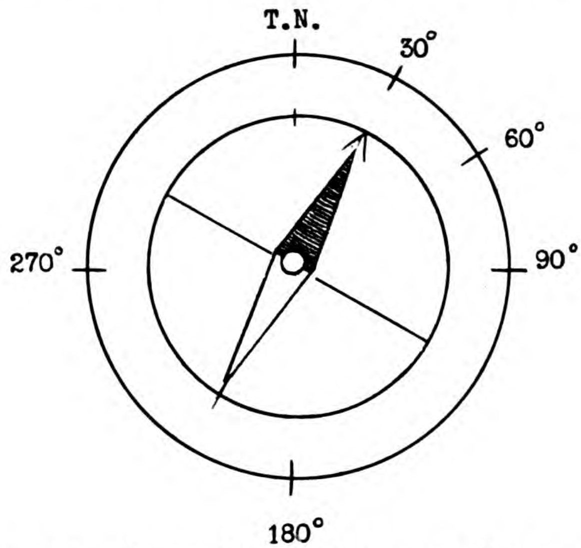
   ANS: ____________________

COMPASS ERROR

1. Variation 10° W.	2. Variation 4° W.	3. Variation 6° E.
Deviation 10° E.	Deviation 5° W.	Deviation 2° E.
No compass error	Compass error 9° W.	Compass error 8° E.
4. Variation 2° E.	5. Variation 5° W.	6. Variation 10° E.
Deviation 4° W.	Deviation 7° E.	Deviation 3° W.
Compass error 2° W.	Compass error 2° E.	Compass error 7° E.

When deviation and variation are lumped together, the net result is known as the total compass error. Sometimes the deviation cancels the variation and the compass then points out true directions. See example 1, above.

Sometimes the deviation combines with the variation so that the sum of the two becomes the total compass error. In such a case both must be east or both must be west as in examples 2 and 3, above. When one is east and the other west, their difference becomes the total compass error as in examples 4, 5 and 6, above.



When the variation is east, the north end of a magnetic compass needle (free from a plane's disturbing influence) points east of true north. You are already familiar with this.

When the compass error is east, the effect of the plane has been taken into consideration, and the north end of the plane's compass needle points east of true north. See diagram above showing 30° E. error.

EXAMPLE PROBLEMS

1. If the variation is 10° W. and the deviation is 5° W., what is the total compass error? What compass heading must be steered to maintain a true heading of 50°?

   ANS: The error is 15° W. The compass heading must be 65°.

2. You are in Boston and wish to maintain a true heading of 40°. The deviation on your compass for headings between East and North is 3° E. What must the compass heading be?

ANS: 52°

CLASSROOM PROBLEMS

1. What compass error results from combining the following values?

Variation 16° W.	Variation 14° E.	Variation 4° E.	Variation 0°
Deviation 3° E.	Deviation 3° W.	Deviation 6° W.	Deviation 5° W.

ANS:

2. What compass headings would have to be steered to maintain the following true headings?

True heading 62°	True heading 308°	True heading 49°
Compass error 21° W.	Compass error 18° E.	Compass error 3° W.

ANS:

True heading 263°	True heading 136°	True heading 352°
Compass error 14° W.	Compass error 16° E.	Compass error 17° W.

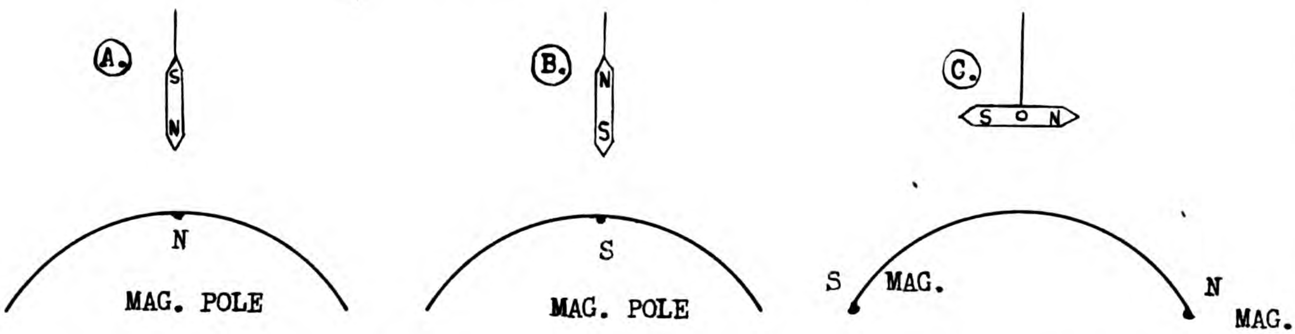
ANS:

3. Is it strictly correct to enter a deviation graph with the true heading instead of the magnetic heading for the purpose of obtaining the proper deviation? What would happen if the deviations were large?

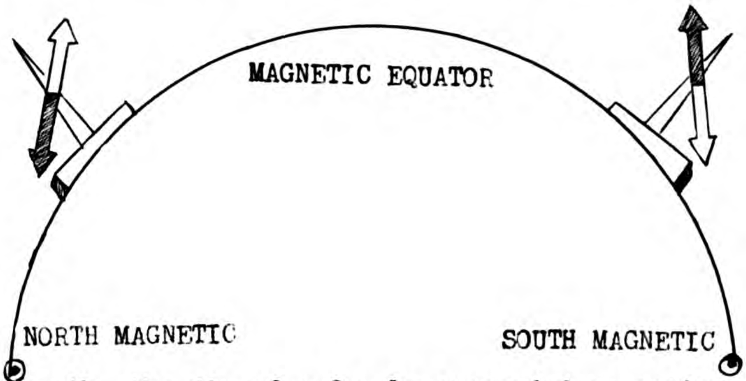
ANS:____

____

EFFECT OF DIP ON COMPASS BEHAVIOR



At the magnetic poles, a freely suspended magnetized needle will dip vertically downward. See A and B above. At the magnetic equator (which is not the same as the earth's equator) the freely suspended needle lies in the horizontal plane as shown at C above.



Elsewhere on the earth, the dip of a freely suspended magnetic needle varies between these two extremes. See the diagram above.

When a part of the total pull on a magnetic compass needle is exerted downward, less of the total pull is available to make the compass needle turn in the horizontal plane toward magnetic north.

NEAR NORTH POLE NEAR MAGNETIC EQUATOR NEAR SOUTH POLE

A magnetic compass has the most horizontal directive force at the magnetic equator and none at all at the north or south magnetic poles. Near the magnetic poles the compass moves so slowly and erratically as to be practically useless.

EXAMPLE PROBLEMS

1. Is the magnetic equator everywhere equi-distant from the north and south magnetic poles?

   ANS: Curiously enough, it is not. The magnetic equator is a line joining all points where no dip has been found to exist.

2. Is the total pull on the compass needle the same for all points equi-distant from the magnetic equator?

   ANS: No it is not. Possibly because of local magnetic disturbances the total pull on the needle has been found to vary considerably at points equi-distant from the magnetic equator.

3. Does the magnetic variation remain constant for any given locality?

   ANS: Generally speaking, no. Various theories have been presented to explain this phenomena. From the navigator's standpoint, however, the reason is of minor importance because the <u>amount of such change per year</u> is printed on his charts near the isogonic lines.

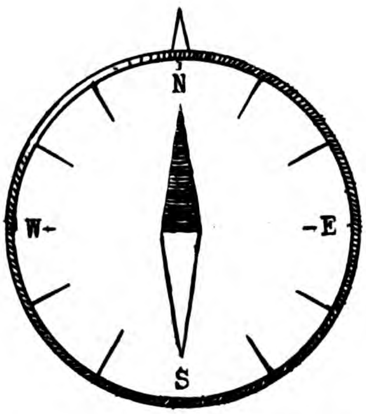
NAVIGATION PRINCIPLES

CLASSROOM PROBLEMS

1. Would you expect the compass to settle down quickly in high latitude?

   ANS:____

NORTHERLY TURNING ERROR



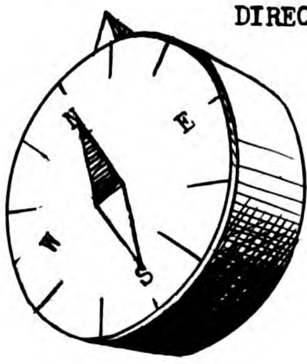
DIRECTION OF FLIGHT

"A"

As long as the compass is kept horizontal, the needle does not dip. The pull may be there, but the compass is constructed so that the needle can only swing from side to side horizontally.

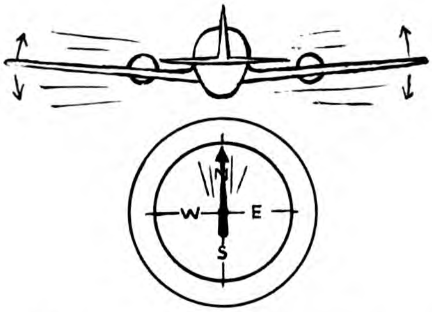
When the compass is tilted up on its side, however, the pivot becomes somewhat horizontal and the needle becomes free to dip. If, when the compass is located well north of the magnetic equator, the compass is tilted as in "A", the north end of the needle is pulled down toward East. The compass indicates a turn to the left even though no turn is being made!

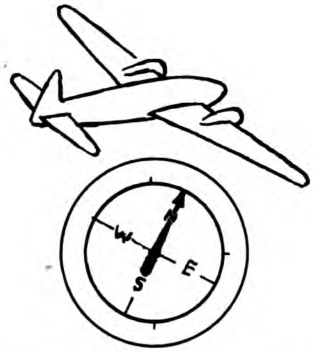
DIRECTION OF FLIGHT



"B"

If the same compass is tilted as in "B", it shows a right turn being made even though the plane keeps its head pointed north.





When making a right turn out of north, two forces act to change the compass heading indication. The turn itself acts to change the heading indication to an easterly heading. During the turn, however, the right wing is lowered. This lowers the east side of the compass and allows the north end of the needle to dip, thereby indicating a left turn to the west.

The heading indicated during such a turn will depend on the relative strength of the two forces acting to turn the compass. If the plane is banked sufficiently during the turn out of north, the compass will indicate a turn in the opposite direction (or a greatly reduced rate of turn in the correct direction). This is known as NORTHERLY TURNING ERROR.

If, when the plane is well north of the magnetic equator, a turn out of south is made, the compass shows an exagerated rate of turn.

EXAMPLE PROBLEMS

1. Does a turning error occur when making a turn out of east or west?

   ANS: Little if any.

2. How could northerly turning error be reduced?

   ANS: Northerly turning error may be reduced by making a flat turn (without banking the plane).

3. How does the behavior of the compass on 180° compare with its behavior on 90° and 270°? Assume the plane is flying in Canada.

   ANS: The compass oscillates much more on 180°.

CLASSROOM PROBLEMS

1. Explain the action of the compass when turning out of south in Australia.

   ANS: ____

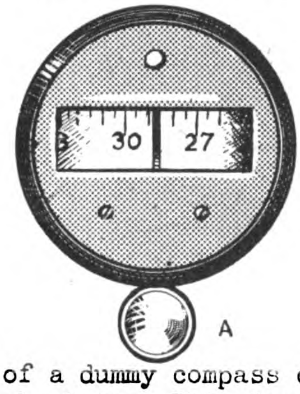
2. Explain the action of the compass when turning out of north in South Africa.

   ANS: ____

3. Could these errors be reduced in any way?

ANS:____

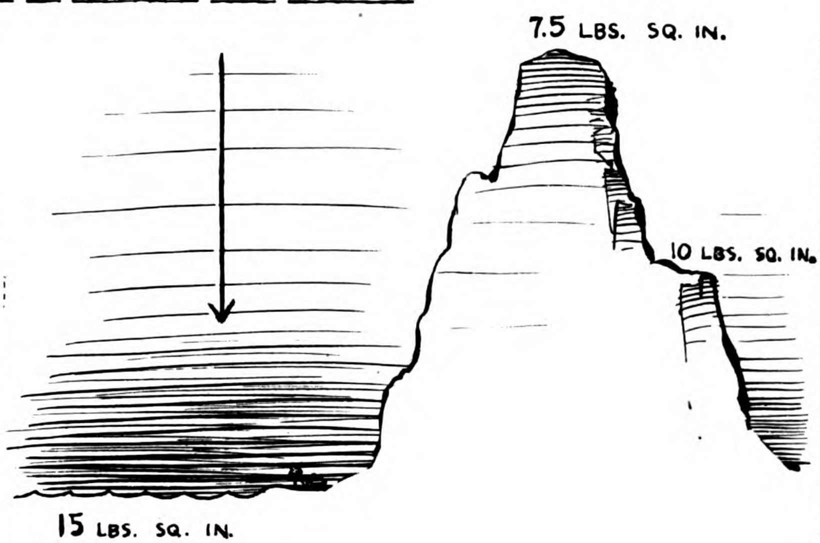
DIRECTIONAL GYRO



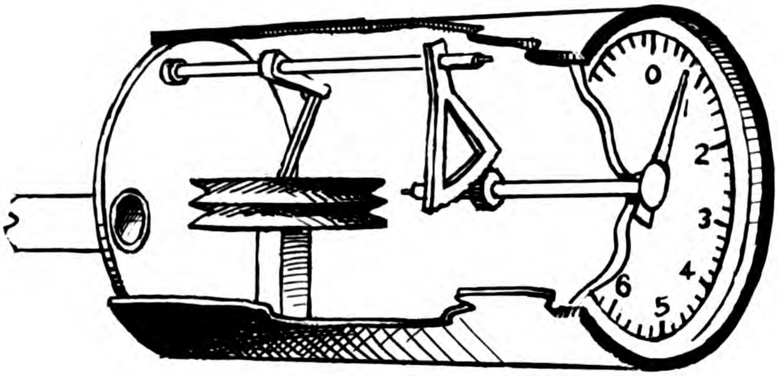
A directional gyro consisting of a dummy compass card mounted on a gyroscopic mechanism is shown in the sketch above. This instrument is read exactly as a compass is read. It is not dependent on magnetism for its operation and hence its indications are much more steady and reliable in both straight flying and in turns.

Unfortunately, it possesses no direction seeking characteristics. It is aligned with the compass by means of knob "A" when the compass is steady. A properly functioning directional gyro will keep this alignment within 3° for a period of several minutes after which it must be re-aligned.

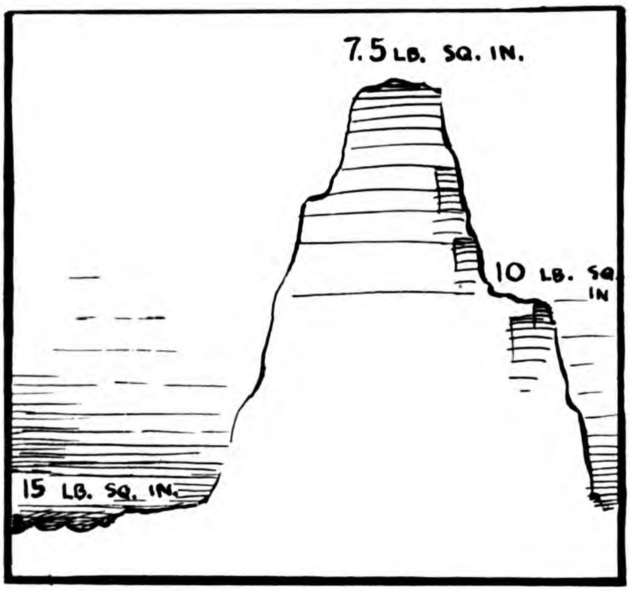
VARIATION OF PRESSURE WITH ALTITUDE

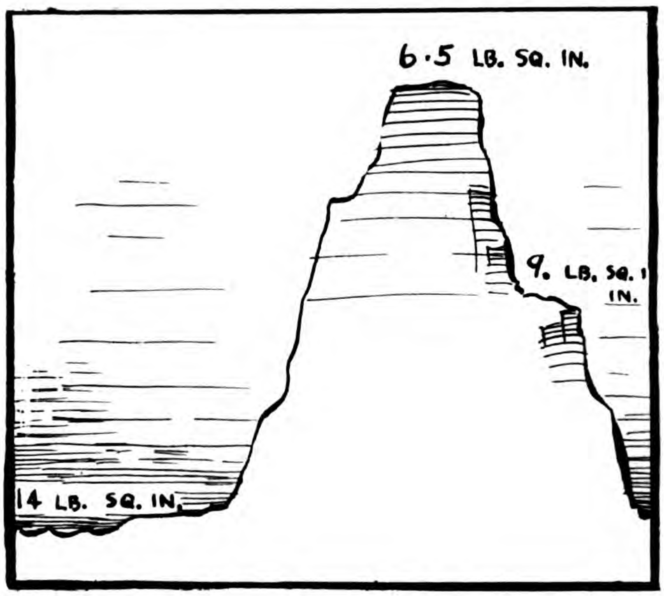


The earth is surrounded by an atomosphere that has a very definite weight. The weight of this air bearing down on the earth amounts, at sea level, to approximately 15 lbs. per square inch. On the top of a high mountain, the pressure of the air is considerably less because there is less air above the mountain.



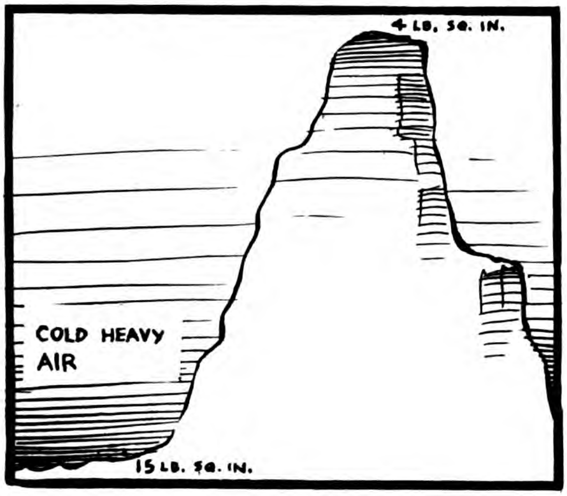
Since the normal pressure at various altitudes is well known, an instrument that that would measure this pressure might be used to determine a plane's altitude provided normal pressures were known to exist. An altimeter is a pressure gauge.

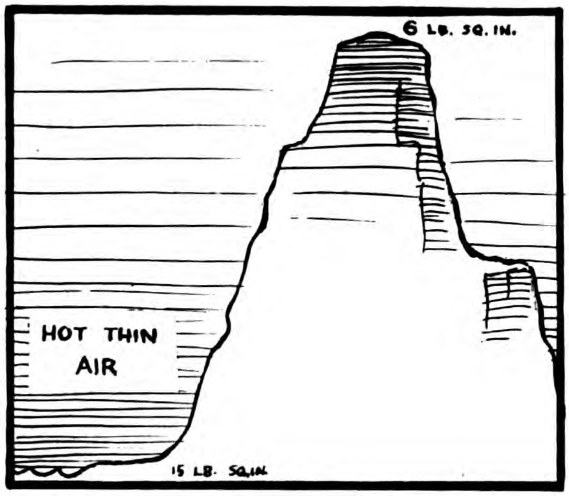




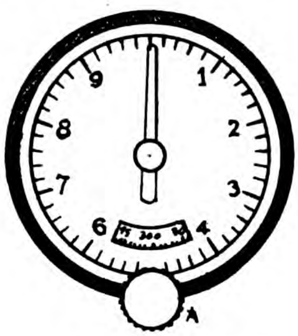
Unfortunately, the weight of air bearing down on the earth at sea level does not remain constant from day to day. This means that "normal" pressure may not occur at the expected altitude. Therefore, a direct measurement of pressure is insufficient to determine altitude. The drop in pressure is actually used.

TEMPERATURE AND WEIGHT OF AIR

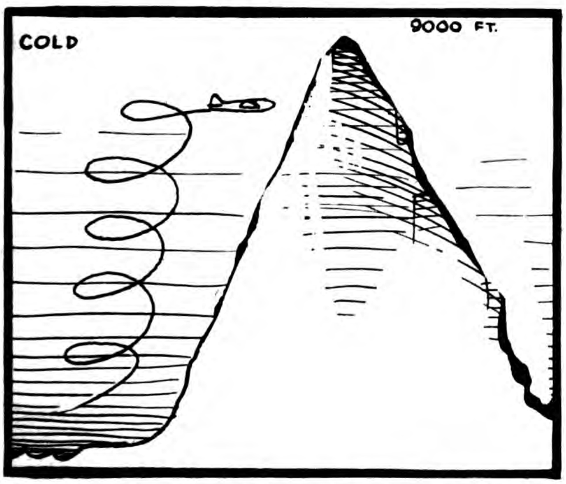


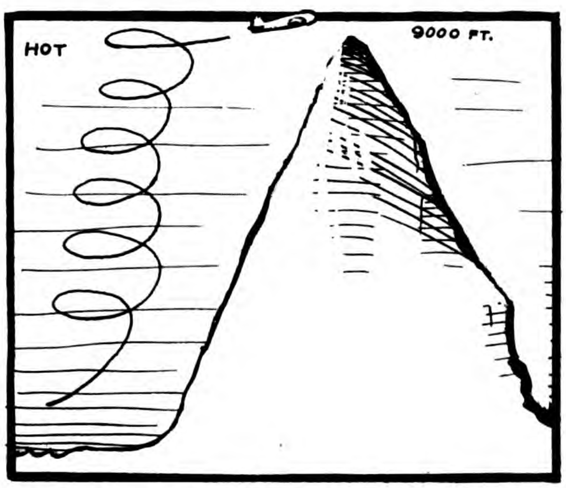


The drop in pressure between sea level and the top of the mountain depends on the density of the air between those two levels. Cold air between sea level and the top of the mountain would be more dense and weigh more than warm or hot air. Thus the pressure drop in cold air would be greater than in warm air.



The altimeter may be set by means of a knob "A" so that it will read zero altitude at sea level. The face markings assume a "standard" pressure dop per thousand feet. Unless the standard pressure drop occurs, the reading of the dial is incorrect.





On a cold day, the plane may climb up through enough very dense air to bring about an altimeter indication of flight altitude before the plane has actually reached that height.

On a warm or hot day, the plane may actually reach a certain altitude before having climbed up through enough hot, thin air to bring about such an indication on the face of the instrument.

EXAMPLE PROBLEMS

1. Is air pressure usually stated in lbs. per square inch?

   ANS: No. The international millibar unit is widely used. Domestic airlines in the U.S. at present use the term "inches of mercury".

2. Explain the term "inches of mercury".

   ANS: A column of mercury will rise about 30 inches in an evacuated tube under a pressure of 15.00 lbs. per square inch. A column of mercury will rise half as high under a pressure half as great (7-1/2 lbs.), etc. Since tubes of mercury are often used on the ground to determine air pressure, the practice of stating the pressure in inches of mercury developed.

3. What is normal sea-level pressure?

   ANS: The normal sea level pressure varies considerably at different places on the earth. This is aside from the day by day changes that occur at those places.

   STANDARD sea level pressure is an arbitrary pressure of 1013 millibars or 29.92 inches of mercury.

4. Is there such a thing as a normal sea level temperature?

   ANS: Obviously the sea level temperature varies from day to day and from season to season. STANDARD sea level temperature is assumed to be 15° above zero Centigrade or the equivalent, 59° Fahrenheit.

CLASSROOM PROBLEMS

1. Give one reason why a direct measurement of air pressure is insufficient to determine the altitude of a plane?

   ANS:____

2. If the exact pressure-drop between sea level and the aircraft were known, could this be used to find the altitude of the plane?

   ANS:____

3. Two planes take off from two widely separated airports. The same sea level pressure exists at each, but at "A" it is very much colder than at "B". Each climbs until its altimeter reads 5,000 ft. Are both planes at the same altitude? Is plane "A" higher or lower than plane "B"? Why?

   ANS:____

4. State the Farhenheit and Centigrade temperatures at which water freezes and boils.

   ANS: ____________________

5. Convert 100° F. to Centigrade. Convert 20° C. to Farhenheit. Convert -10° F. to Centrigrade.

   ANS: ____________________

PRESSURE DROP WITH ALTITUDE

		23.50	5,000 ft. alt.
		24.50	4,000 ft. alt.
		25.50	3,000 ft. alt.
		26.50	2,000 ft. alt.
29.00	1,000 ft. alt.	27.50	1,000 ft. alt.
30.00	Sea Level	28.50	Sea Level

Normal pressure-drop is nearly one inch (of mercury) per thousand feet of altitude. If pressure of 30.00 inches exists on the surface of the sea, a pressure of approximately 29.00 inches will exist 1,000 ft. above sea level.

If the sea level pressure is 28.50 inches on some particular day, the pressure at 5,000 ft. will be approximately 23.50 inches.

26.00		25.00
	Same Temperature	
	Same pressure drop per 1,000 ft.	
30.00	SEA LEVEL	29.00

Even though different sea level pressures exist as shown above, the pressure-drop with altitude above sea level will be nearly the same at any <u>one</u> given temperature.

Under this condition of different sea level pressures, an altimeter set to read zero at the surface of either area will show correct altitude after a climb provided the temperature of the column of air beneath the plane is STANDARD.

		4,000
	4,000 true alt.	
4,000	3,000	
	2,000	
	1,000	
30.00 or 29.00	SEA LEVEL	30.00 or 29.00

With either sea level pressure at the left, the altimeter will indicate more than the actual altitude of the plane if the air column is colder than STANDARD.

With either sea level pressure at right, the altimeter will indicate less than the actual altitude of the plane if the air column is warmer than STANDARD.

EXAMPLE PROBLEMS

1. If you have set your altimeter to read zero at sea level, will it show correct altitudes thereafter?

   ANS: Not unless the temperature of the air column through which you have climbed is standard.

2. The sea level pressure was known to be 28.92 instead of 29.92, when you set your altimeter to read zero. Would you have to take this into consideration after the new setting has been made?

   ANS: No, just the temperature of the air column.

3. Prior to taking off from an airport 5,000 ft. above sea-level, you set your altimeter to read 5,000 ft. Will it show 10,000 ft. after you have climbed another 5,000 ft?

   ANS: Yes, if the temperature of the column of air from the airport to 10,000 ft. agrees with the standard of that column; otherwise, no!

CLASSROOM PROBLEMS

1. Prior to taking off from a lake at an altitude of 5,000 ft. you set your altimeter to read 5,000 ft. Will it read zero when you land at sea-level?

   ANS: ____________________

2. You take off from a sea level airport with altimeter set to read zero. The sea level pressure is 30.00 inches. It is colder than standard. You return in the afternoon when the sea level pressure is the same but the temperature is much warmer than standard. You circle the field and note that your altimeter indicates 2,000 ft. Are you above or below 2,000 ft.?

   ANS: ____________________

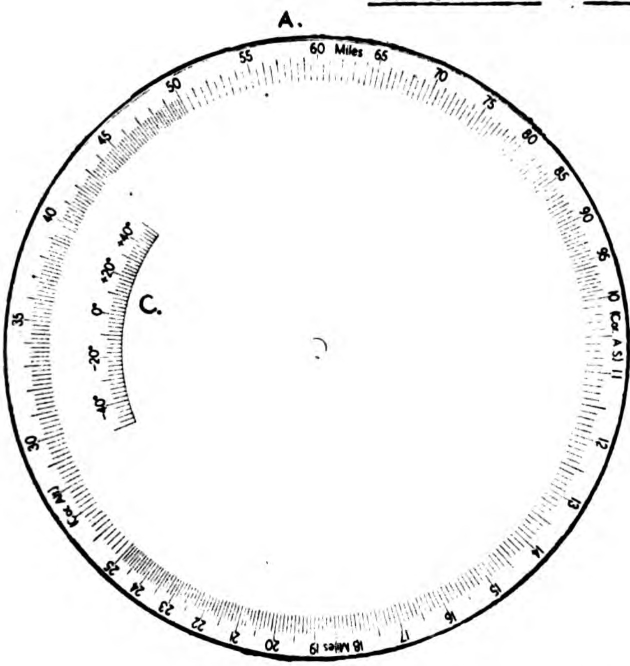
3. You fly cross-country where the sea level pressure is the same. You gradually pass from an area warmer than standard into an area where the temperature is much colder than standard. You maintain a constant indicated altitude of 5,000 ft. Is your plane descending, climbing, or staying at 5,000 ft. altitude?

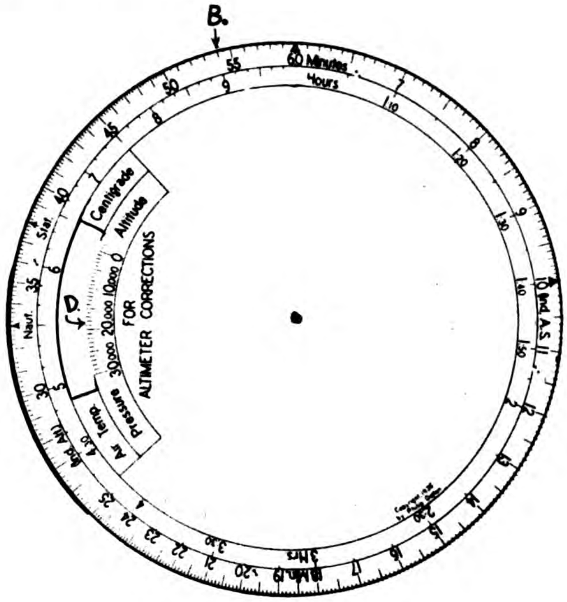
ANS: ____

4. Which is more dangerous from a safe altitude standpoint, flying from a cold to a warm area or flying from a warm to a cold area?

ANS: ____

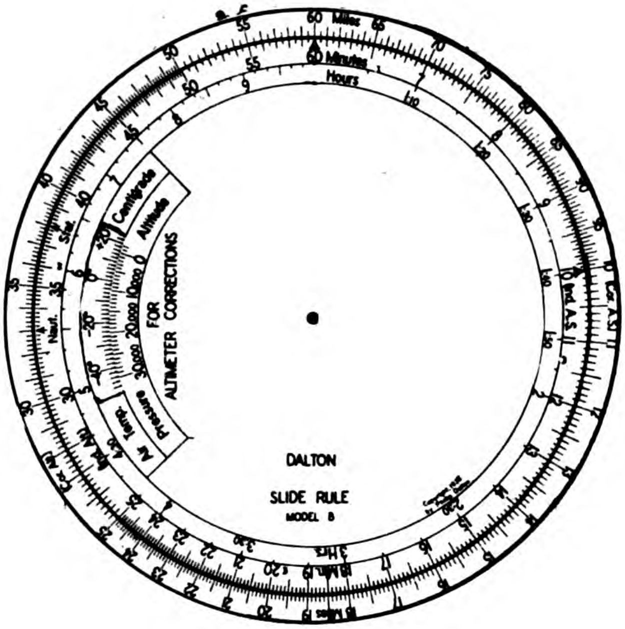
CALCULATORS - ALTIMETER CORRECTION





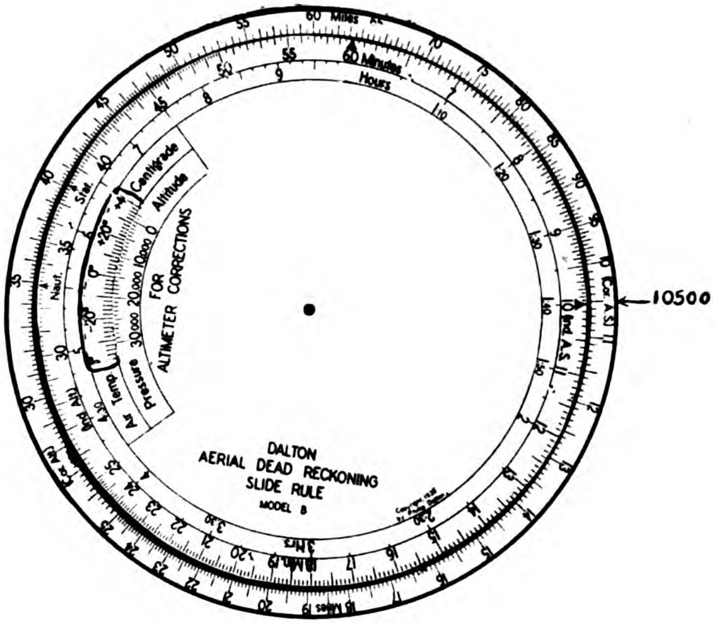
As long as the navigator knows his altimeter is set to read zero at sea level beneath him, he may find out his correct altitude by correcting the altitude shown on his altimeter for any error caused by a non-standard temperature condition of the air column beneath the plane. A computer used for this purpose is shown disassembled above.

Scale "A" is a scale of corrected altitudes; 40 equals 4,000 ft., etc.
Scale "B" is a scale of indicated altitudes; 40 equals 4,000 ft., etc.
Scale "C" is a scale of standard temperatures.
Scale "D" is a scale of altitudes at which those temperatures normally occur.



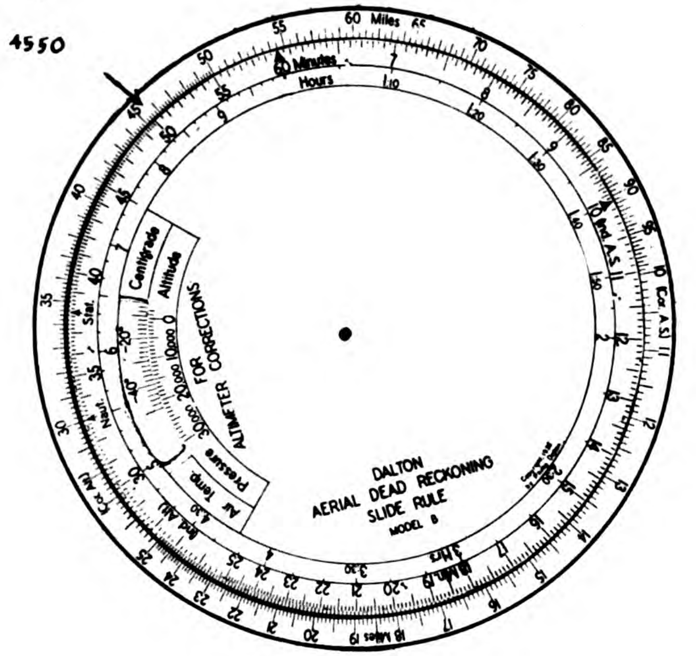
The computer is shown assembled in this sketch. As it is shown here, the indicated altitude of 4,000 ft. on scale "B" is opposite and therefore equal to the correct altitude 4,000 ft.

Since all indicated altitudes and correct altitudes shown are the same, it follows logically that the air temperature conditions must be standard. Reference to scales "C" and "D" shows this to be true. The standard temperature at 10,000 ft. is -5°C., the standard temperature at 20,000 ft. is -25°C., and at sea-level the standard temperature is +15°C. These values have been chosen as standard for uniformity.



If the navigator knew his altimeter was set to show zero at sea level, but observed an outside air temperature of $+10^{\circ}$C. at an indicated altitude of 10,000 ft., he would set the computer as shown above.

10,000 ft. on scale "D" is set opposite $+10^{\circ}$ on scale "C". In doing this 10,000 ft. on the indicated altitude scale "B" becomes placed opposite the correct altitude on scale "A". The correct altitude is therefore 10,550.



In this case, the navigator observes an outside air temperature of -20° C. at an indicated altitude of 5,000 ft. 5,000 on scale "D" is set opposite -20° C. on scale "C". The correct altitude is shown on the outer scale "A", opposite 5,000 on the indicated altitude scale "B". The plane is 4,550 ft. above sea level.

In correcting these indicated altitudes, we have assumed that the navigator has his altimeter set to show zero altitude at sea level.

It is also assumed that a non-standard temperature at flight altitude proved the existence of a non-standard column of air beneath the plane. The navigator of ocean flying planes generally has to assume this to be true; actually there may be layers of warm and cold air between him and the surface that would disprove his assumption.

EXAMPLE PROBLEMS

(Assume the altimeter set to show zero altitude at sea level)

1. An outside air temperature of -10° C. is observed at an indicated altitude of 10,500 ft. What is the correct altitude?

   ANS: 10,320 ft.

2. An outside air temperature of +15° C. is observed at an indicated altitude of 8,300 ft. What is the correct altitude?

   ANS: 8,775 ft.

3. An outside air temperature of -20° C. is observed at an indicated altitude of 11,100 ft. What is the correct altitude?

   ANS: 10,550 ft.

4. An outside air temperature of -23° C. is observed at an indicated altitude of 4,200 ft. What is the correct altitude?

ANS: 3,760 ft.

CLASSROOM PROBLEMS

(Assume the altimeter set to show zero altitude at sea level.)

1. An outside air temperature of $+12^\circ$ C. is observed at an indicated altitude of 6,000 ft. What is the correct altitude?

ANS:____________________

2. An outside air temperature of -15° is observed at an indicated altitude of 11,500 ft. What is the correct altitude?

ANS:____________________

3. An outside temperature of $+5^\circ$ is observed at an indicated altitude of 11,500 ft. What is the correct altitude?

ANS:____________________

4. At what temperature will an indicated altitude of 6,000 ft. be correct?

ANS:____________________

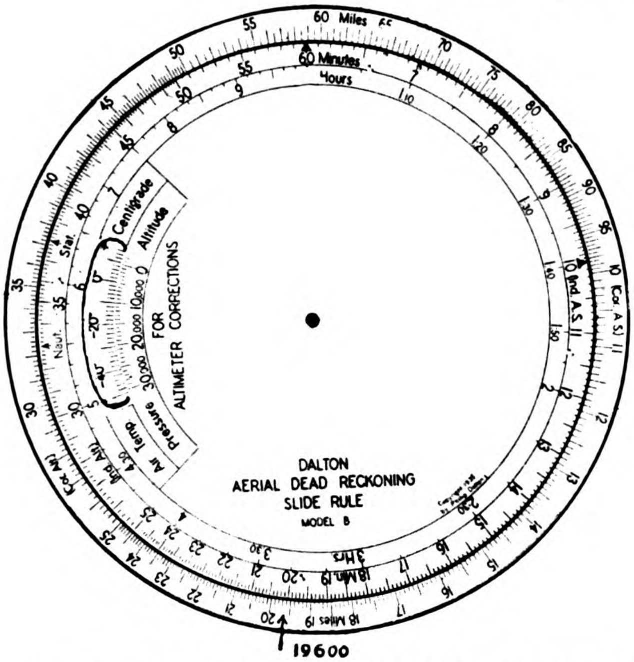
5. An outside air temperature of -25° C. is observed at an indicated altitude of 4,000 ft. What is the correct altitude?

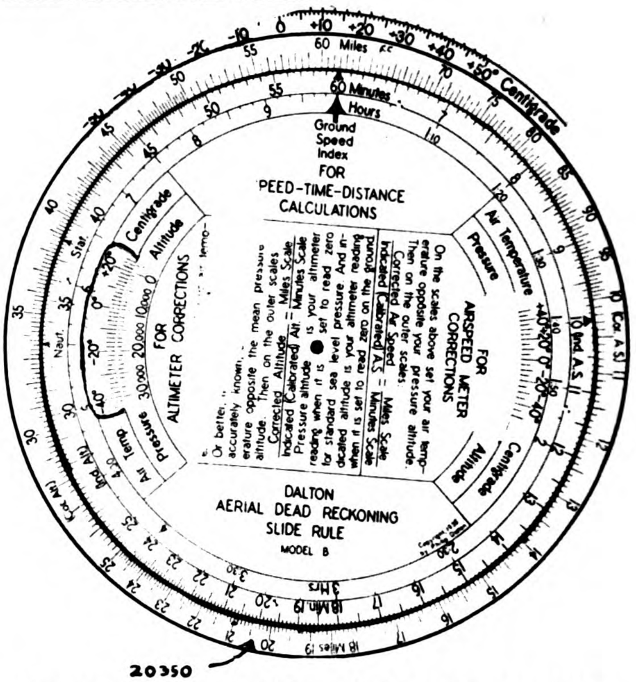
ANS:____________________

6. Can you ever be certain that a non-standard column of air exists between your plane and sea level by noting the outside air temperature at the indicated flight altitude? Why?

ANS:____________________

USE OF AVERAGE TEMPERATURE ABOVE SEA LEVEL





A more accurate determination of correct altitude is possible if the temperature at sea level beneath the plane is known in addition to that at the flight altitude.

If the temperature is 0° C. at the surface and -20° C. at an indicated flight altitude of 20,000 ft., the temperature at 10,000 ft. should be -10°C.

With this information, set 10,000 ft. opposite -10° C., shown at left above, instead of 20,000 ft. opposite -20°C., as at right above, before reading the correct altitude opposite the indicated altitude.

If this better method is used, the correct altitude is shown to be 19,600 ft. whereas the method formerly used would have shown the correct altitude to be 20,350 ft.

EXAMPLE PROBLEMS

(Assume that the altimeter has been set to show zero altitude at sea level)

1. An outside air temperature of -8° C. is observed at an indicated altitude of 10,000 ft. The sea level temperature is reported to be + 8° C. What is the correct altitude?

   ANS: 9,800

2. An outside temperature of +10° C. is observed at an indicated altitude of 5,500 ft. The sea level temperature is reported to be 0° C. What is the correct altitude? Note the temperature inversion.

   ANS: 5,400

CLASSROOM PROBLEMS

(Assume the altimeter to be set to read zero altitude at sea level)

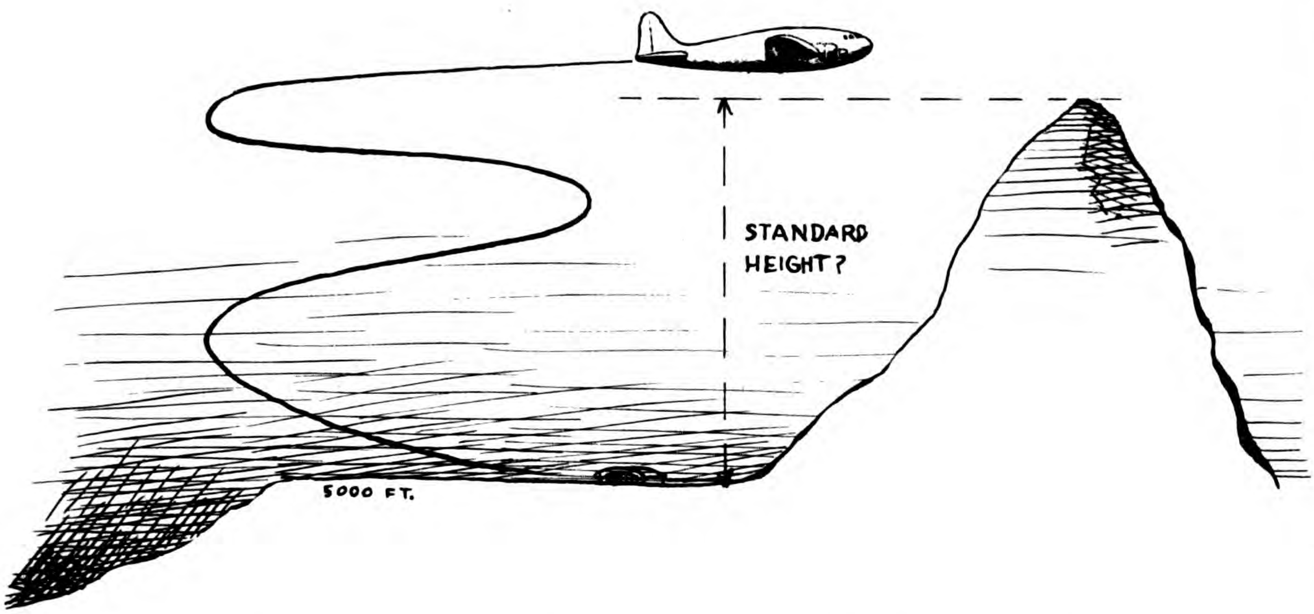
1. An outside air temperature of -20° is observed at an indicated altitude of 5,000 ft. The sea level temperature is reported to be -5° C. What is the correct altitude?

ANS: ____________________

2. An outside air temperature of -10° C. is observed at an indicated altitude of 10,000 ft. The sea level temperature is reported to be -2° C. What is the correct altitude?

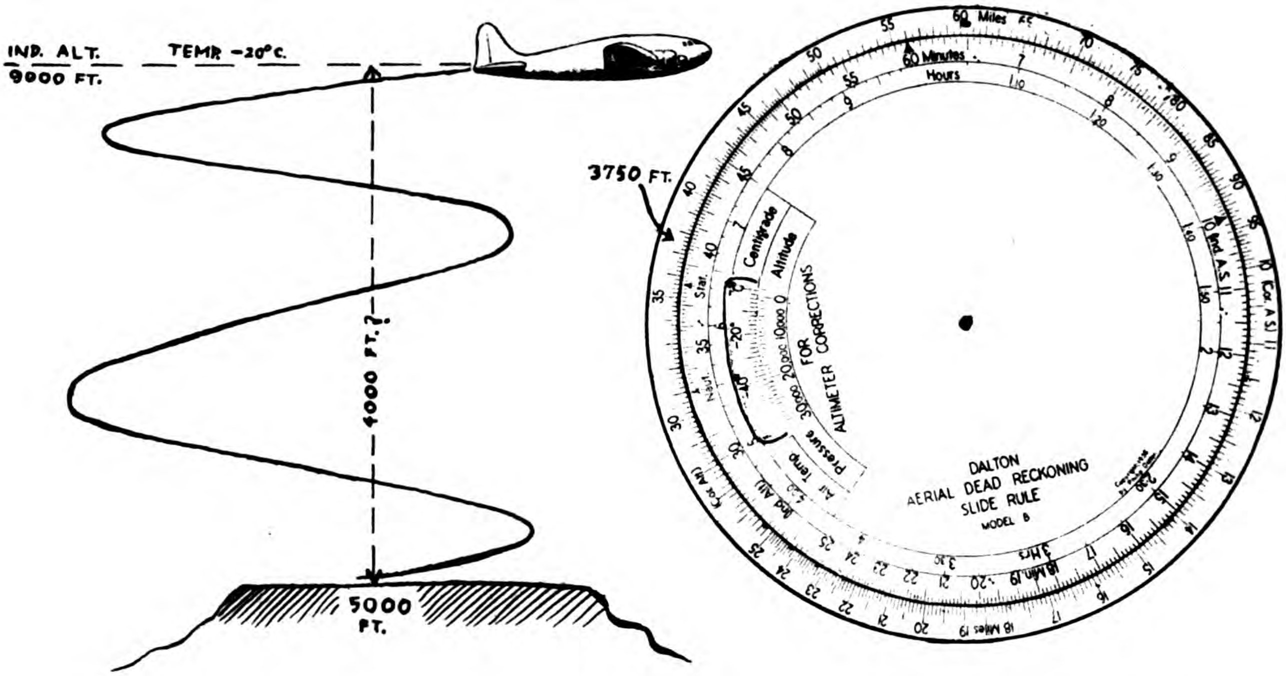
ANS: ____________________

DETERMINING ALTITUDE ABOVE AIRPORTS



It was stated before that an altimeter set to read 5,000 ft. at a 5,000 ft. airport would __not__ indicate correct altitudes thereafter unless the air column, through which the plane climbed, were of standard temperature.

When the air column is non-standard, the correction problem is a problem of determining the height of the column of air through which the plane climbed __after leaving the airport__.



In the diagram above, a plane climbs to an indicated altitude of 9,000 ft. after the navigator set the altimeter to read 5,000 ft. at a 5,000 ft. airport. At the indicated 9,000 ft. altitude, the outside air temperature is -20°C. The correct altitude of the plane is determined in the following manner:

Using scales "C" and "D", set 9,000 opposite -20° C. The correct height of the column of air above the airport is shown on the outer scale opposite 4,000 ft. on the inner scale; i.e., 3,750 ft.

The plane is therefore 5,000 plus 3,750 or 8,750 ft. above sea level.

EXAMPLE PROBLEMS

(Assume the altimeter set to show field altitude when on the field.)

1. A plane took off from a 2,000 ft. airport and climbed to an indicated altitude of 8,000 ft. where the temperature was -10°C. What was the correct altitude of the plane?

   ANS: 7,800 ft.

2. A plane took off from a 6,000 ft. airport and climbed to an indicated altitude of 12,000 ft. where the temperature was -5°C. What was the correct altitude of the plane?

   ANS: 12,075 ft.

CLASSROOM PROBLEMS

(Assume the altimeter set to shown field altitude when on the field)

1. A plane took off from a 4,000 ft. airport and climbed to an indicated altitude of 12,000 ft. where the temperature was 0° C. What was the correct altitude of the plane?

   ANS: ______________________________

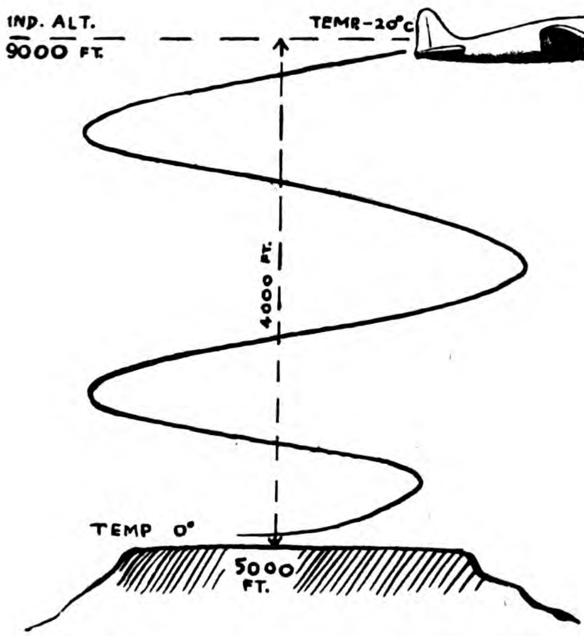
2. A plane took off from a 3,400 ft. airport and climbed to an indicated altitude of 7,800 ft. where the temperature was -10° C. What was the correct altitude of the plane?

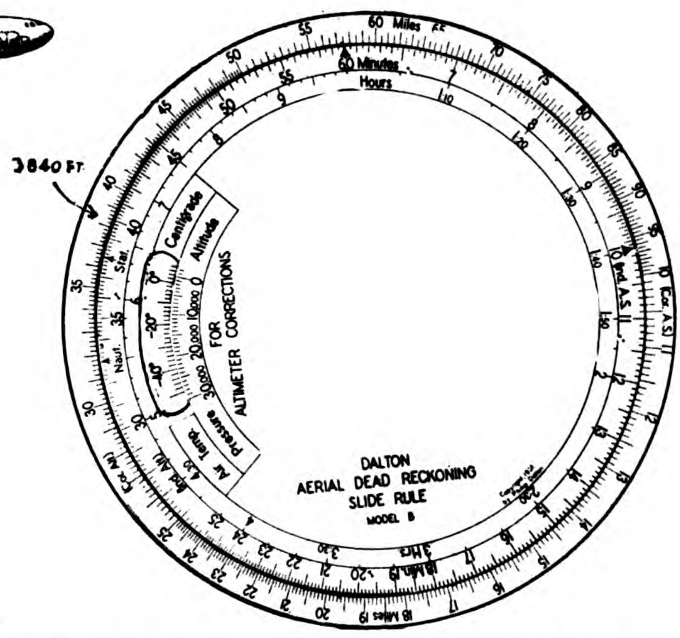
   ANS: ______________________________

3. You take off from a 5,600 ft. airport and climb to an indicated altitude of 11,100 ft. where the temperature is -20° C. What is the correct altitude of your plane?

   ANS: ______________________________

USE OF AVERAGE TEMPERATURE ABOVE AIRPORT





If the temperature at the airport is known, a more accurate knowledge of the plane's altitude may be obtained as follows:

> Using scales "C" and "D", set the mean temperature between your plane and the airport opposite the mean altitude between your plane and the airport. Then proceed as before.

In the diagram, the altimeter was set to 5,000 ft. before take-off. The temperature at the field was 0° C. At the indicated 9,000 ft. altitude the temperature was -20° C. The computer setting shows 7,000 opposite -10° C. The correct height of the column of air above the airport (3,840 ft.) appears on the "A" scale opposite 4,000 ft. on the "B" scale. The plane is 8,840 ft. above sea level.

EXAMPLE PROBLEMS

(Assume the altimeter set to field altitude when on the field)

1. You take off rom a 5,000 ft. airport where the temperature is $+10^{\circ}$C. and climb to an indicated altitude of 12,000 ft. where the temperature is -10° C. What is the altitude of your plane?

   ANS: 12,040 ft.

2. You take off from a 3,000 ft. airport where the temperature is -2° C. and climb to an indicated altitude of 7,000 ft. where the temperature is -10° C. What is the correct altitude of your plane?

   ANS: 6,840 ft.

CLASSROOM PROBLEMS

(Assume the altimeter set to field altitude when on the field)

1. You take off from a 2,400 ft. airport where the temperature is $+20^{\circ}$C. and climb to an indicated altitude of 5,500 ft. where the temperature is 0°C. What is the correct altitude of your plane?

   ANS:____

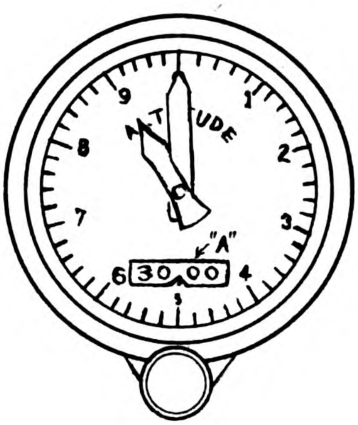
2. You take off from a 3,300 ft. airport where the temperature is -1°C. and climb to an indicated altitude of 5,000 ft. where the temperature is $+10^{\circ}$ C. What is the altitude of your plane?

   ANS:____

3. You take off from a 6,200 ft. airport where the temperature is $+15^{\circ}$ C. and climb to an indicated altitude of 14,000 ft. where the temperature is -15° C. What is the altitude of your plane?

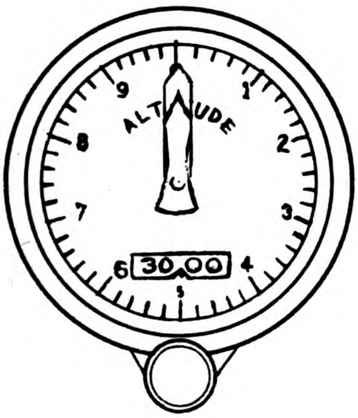
   ANS:____

PRESSURE SETTINGS



Nearly all altimeters are provided with a pressure indicator such as that shown at "A" in the diagram. This indicator shows the pressure level above which altitude on the face of the instrument is measured.

The 9,000 ft. indicated altitude shows that the plane has climbed up through enough air to create a 9,000 ft. pressure drop with reference to the 30.00 inch pressure level.



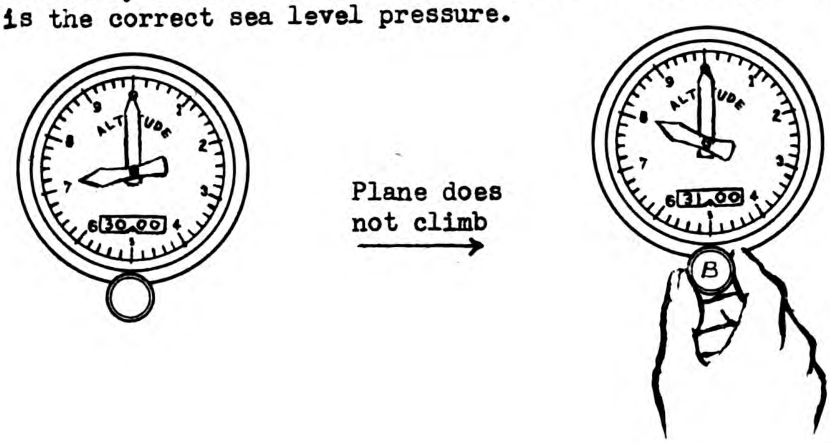
Sea level pressure 30.00 inches

The hands of the altimeter and the pressure indicator are so geared to knob "B" that a movement of the hands by means of the knob also brings about a change in the pressure setting.

If the altitude is changed BY MEANS OF THIS KNOB, the pressure indication changes to show the new pressure level above which the navigator wishes to measure his altitude.

If the plane, at right, is at sea level and the navigator makes the instrument

read zero altitude by means of this knob, the pressure that appears at the pressure window is the correct sea level pressure.



7,000 ft. indicated altitude
sea level pressure 30.00

Altimeter indicates plane 8,000 ft. above newly reported sea level pressure 31.00 in.

Thereafter, the altimeter will indicate altitudes above this pressure level. These altitudes must be corrected for non-standard air column temperatures. All the pressure window shows is the pressure level above which that corrected altitude is measured. <u>If</u> that pressure continues in existance at the surface of the sea, the corrected altitude may be measured above sea level.

If the navigator is advised that the sea level pressure has changed, he must set the new sea level pressure by means of the knob "B". In so doing, the altimeter hands will move a corresponding amount and thereafter indicate altitudes above this new pressure level.

EXAMPLE PROBLEMS

1. Does the pressure indication keep changing as the plane gains altitude?

   ANS: No. The pressure drop experienced with an increase of altitude causes the hands to show more altitude above the pressure level set on the instrument, but it does not change the pressure level above which that altitude is measured.

2. Can the altimeter setting knob set either the hands or the pressure?

   ANS: One cannot be changed without changing the other BY MEANS OF THE KNOB.

3. A pilot climbs to an indicated altitude of 1,000 ft. above a sea level airport where the pressure is 30.00 inches. Before take-off his altimeter read zero altitude and the pressure setting read 30.00 inches.

   He maintains an indicated altitude of 1,000 ft. and flies into an area where the sea level pressure is 29.00 inches.

   Is the plane still 1,000 ft. above the 30.00 inch pressure level?

   ANS: Yes, but the plane will be dangerously low or have hit the ground.

This is what happened. The plane climbed to 1,000 ft. at airport "A". It climbed to a position where the air pressure around the plane was 29.00 inches. His altimeter showed him to be 1,000 ft. above the 30.00 inch pressure level. In all probability his correct altitude was very close to 1,000 ft. at the start. Nevertheless, his plane was zero feet above the 29.00 inch pressure level. When he arrived at the area where the pressure of 29.00 inches existed on the surface, he was in trouble -- though still 1,000 ft. above the 30.00 pressure level.

4. How could the pilot have avoided this dangerous situation?

ANS: If he desired to maintain a minimum flight altitude of 1,000 ft., he should have set his altimeter to show altitudes above the minimum sea level pressure expected along the route.

In the absence of detailed pressure condition information at the start of the flight, he should have flown high.

If he could not fly high, he should have made a point of obtaining sea level pressures along the way, and these should have been set on the instrument by means of the pressure setting knob. Had this been done, he would have known his altitude above sea level. It has been assumed that this flight was made on instruments and that the pilot was unable to check his altitude by visual means.

CLASSROOM PROBLEMS

1. A pilot takes off from a sea level airport where the pressure is 29.50 inches. Before take-off, he sets the 29.50 pressure on his altimeter and the hands of the altimeter show zero altitude.

He climbs to an indicated altitude of 8,000 ft. and maintains this indicated altitude throughout the trip. 600 miles out, the sea level pressure increases to 30.00 inches; 600 miles further the sea level pressure decreases to 29.50.

Draw a diagram showing how the actual altitude of the plane changed.

ANS:

2. In the problem above, was the indicated altitude always 8,000 ft. above the 29.50 pressure level? If not, what was the approximate altitude above sea level when the plane was 600 miles out?

ANS:______________________________________

3. In problem 1 above, what would the indicated altitude be if the pilot set the pressure of 30.00 inches on his altimeter when 600 miles out?

ANS:______________________________________

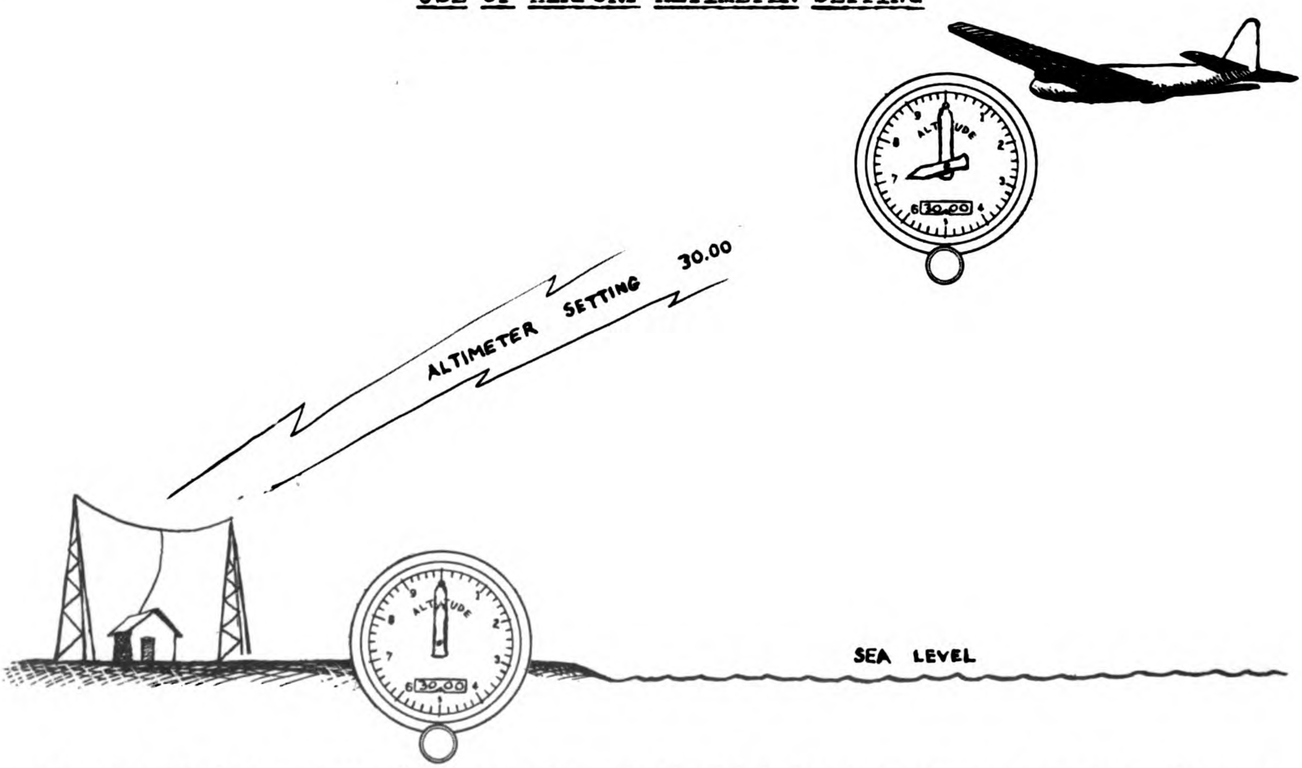
4. In problem #3 above, the outside air temperature at the indicated altitude is observed to be -20° C. Will the plane safely fly over a 7,500 ft. mountain?

ANS:______________________________________

5. Which is more dangerous from a safe altitude standpoint; to fly from an area of high pressure to an area of low pressure, or to fly from an area of low to high pressure?

ANS:______________________________________

USE OF AIRPORT ALTIMETER SETTING

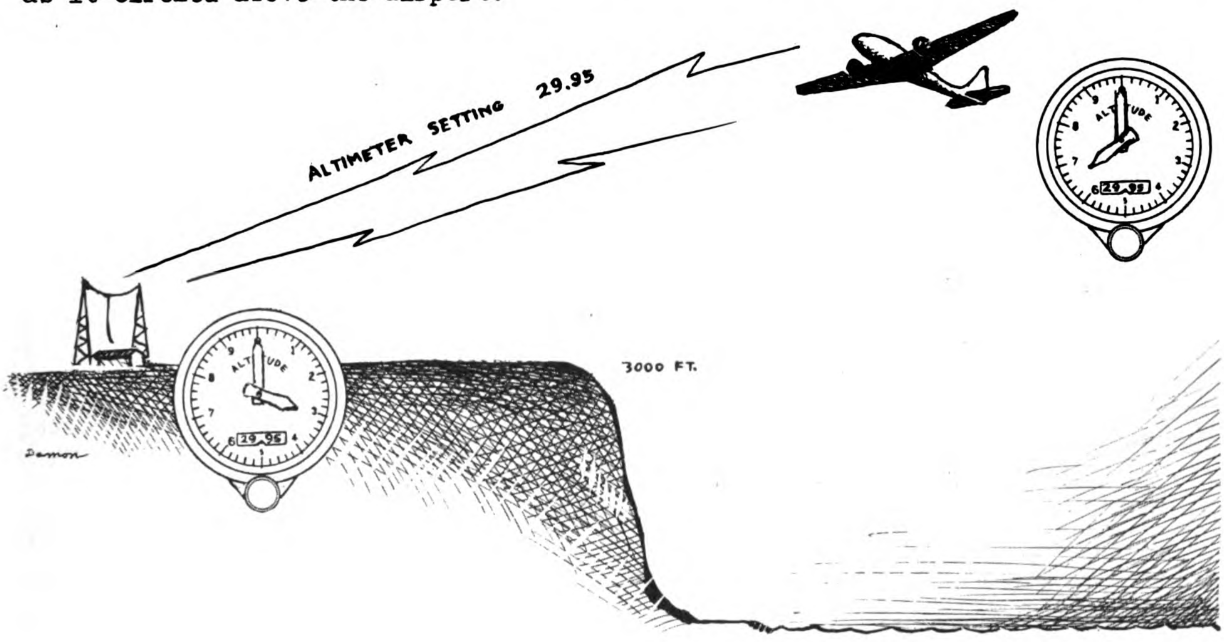


When a pilot is approaching an airport at which he intends to land his plane, he makes a request by radio for the "altimeter setting" of that airport.

When preparing to land at a sea level base, the airport furnishes him with the sea level pressure which he sets on his altimeter. After setting this pressure on his

altimeter, the pilot proceeds with his approach and on landing his altimeter should read zero (provided it does not lag).

From what has already been said about temperature of air columns, it should be apparent that the indicated altitude of the plane was probably somewhat in error as it circled above the airport.



When approaching a high altitude airport, the procedure is the same. The pilot requests the altimeter setting and sets it on his altimeter. He is not necessarily furnished sea level pressure; he is furnished with an altimeter setting which, when used, will enable him to land on the airport with his altimeter indicating the actual altitude of the field.

EXAMPLE PROBLEMS

1. Why isn't sea level pressure used for an altimeter setting when a plane wishes to land on a high airport?

   ANS: If he landed at the sea level airport with this altimeter setting, his altimeter would read zero, but with this setting, an altitude of 3,000 ft. would not necessarily be indicated when the plane arrived at the precise level of the 3,000 ft. airport.

2. If you were flying across an ocean without knowledge of the sea level pressure, what would you do?

   ANS: Set standard pressure of 29.92 inches (1013 millibars) on the altimeter and make a liberal allowance for any possible difference between this pressure level and sea level pressure.

3. What does the term pressure altitude mean?

ANS: Pressure altitude is the indicated altitude of the plane above the standard pressure level of 29.92 inches (1013 millibars).

CLASSROOM PROBLEMS

1. Under what conditions would the altimeter setting for a high airport be the same as sea level pressure?

ANS:____

2. You have received an altimeter setting from an airport 6,000 ft. high and have set this pressure on your altimeter. What will your altimeter read when you land?

ANS:____

3. In problem 2 above, you circle the airport and note that your altimeter reads 7,000 ft. Is your correct altitude very close to 7,000 ft.?

ANS:____

4. In problem 2 above, you pass over the field with your altimeter reading 12,000 ft. Is your correct altitude very close to 12,000 ft.?

ANS:____

5. The temperature at the 6,000 ft. airport which has furnished you an altimeter setting is 0° C. At your indicated altitude of 7,000 ft. the temperature is -4° C. What is your correct altitude?

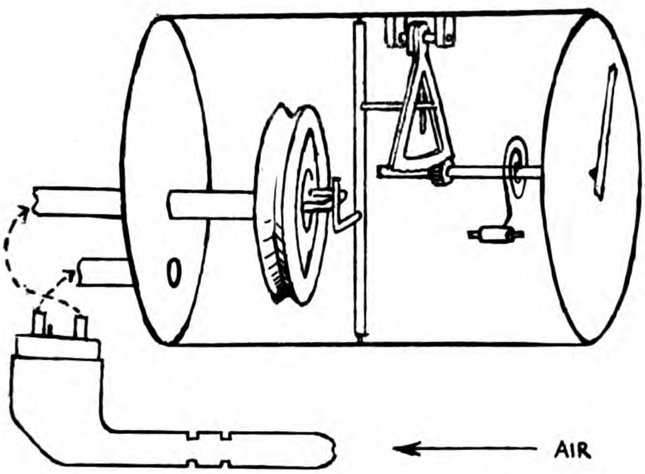
ANS:____

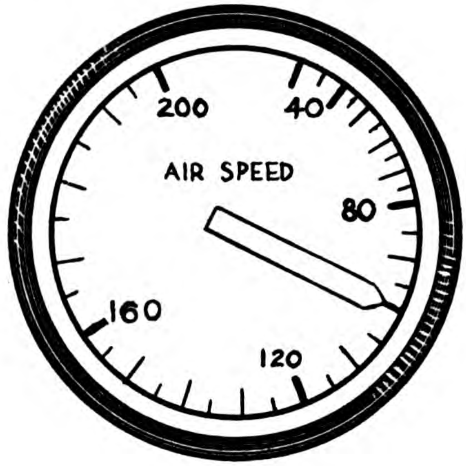
6. The temperature at the 6,000 ft. airport which has furnished you an altimeter setting is -10° C. At your indicated altitude of 12,000 ft., the temperature is -24° C. What is your correct altitude?

ANS:____

NOTE: The terms "Kollsman number" and "altimeter setting" are synonymous. The ZERO landing system employs "Field pressure" or "pressure altitude" of the field. MADE SURE OF YOUR INFORMATION.

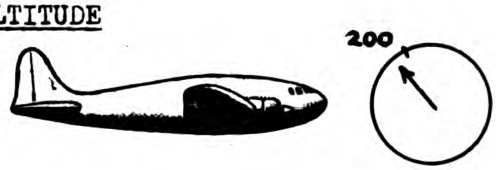
AIRSPEED INDICATORS





The function of an airspeed indicator is to show the speed of the plane through the air. In doing this, the head pressure built up by the plane is made to act against the static (still) air pressure surrounding the plane. The difference in pressures is recorded on the face of the instrument in terms of speed.

INDICATED AIRSPEED vs. ALTITUDE



Above sea level airspeed reads too **low**

Correct indication

1013 mb pressure   Temp. 15° C

Sea Level

Airspeed indicators are designed so that they indicate correct airspeeds when used in an atmospheric pressure of 29.92 inches (1013 millibars) and temperature of 59° F. (15° C.)

They will also indicate correctly in an atmosphere where existing combinations of air pressure and temperature result in the same air density. Such combinations are <u>encountered</u> <u>rarely</u> and then only at <u>very</u> <u>low</u> <u>altitudes</u>.

The density of the air decreases with decreased air pressure.

The density of the air increases with a drop in temperature.

As the altitude increases air pressure decreases faster than the temperature so that a net loss of density results. Because of this reduced density an <u>airspeed indicator shows less than true airspeeds except near sea level</u>.

EXAMPLE PROBLEMS

1. The standard temperature for 10,000 ft. is -5° C. Will an airspeed indicator indicate true airspeeds if this standard temperature exists at 10,000 ft.?

   ANS: No. The fact that standard temperature exists does not mean that standard sea level density exists.

2. About how much difference will there be between indicated and true airspeeds under the conditions of problem 1?

   ANS: The airspeed indicator will read 120 MPH when the true airspeed is actually 140 MPH. If it reads 240 MPH, the true airspeed is actually 280 MPH, etc.

CLASSROOM PROBLEMS

1. What factors effect the density of the air?

   ANS:______________________________

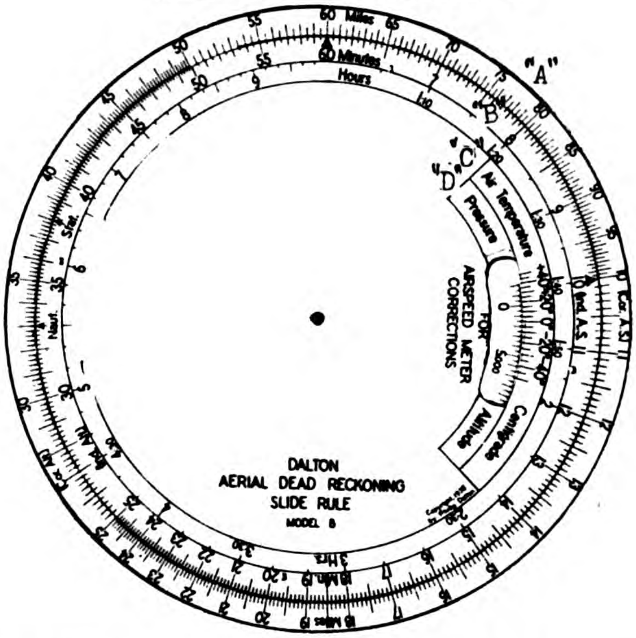
2. Is the air density higher when it is raining?

   ANS:______________________________

3. You are at an altitude of 10,000 ft. and your airspeed indicator reads 120 MPH. You are maintaining a constant true airspeed. If it gets warmer, will your indicated airspeed increase or decrease?

   ANS:______________________________

TRUE AIRSPEED COMPUTER

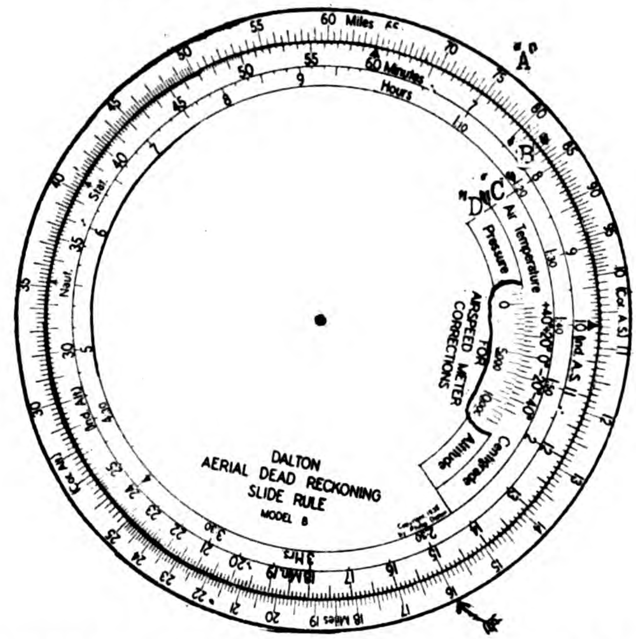


A computer is used to correct indicated to true airspeed. It is illustrated in the figure above; in appearance it is similar to the part of a computer used for correcting indicated altitudes.

The circular scale "A" shows true airspeeds. The circular scale "B" shows indicated airspeeds. Scales "C" and "D" are air temperature and pressure altitude scales respectively.

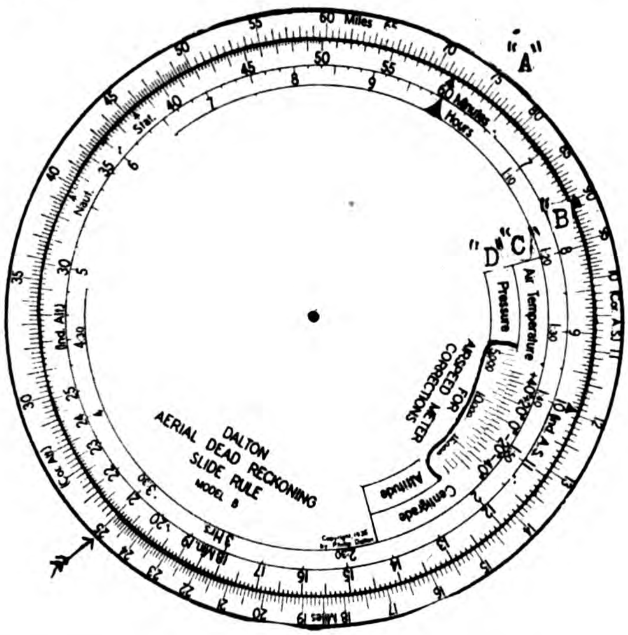
As the computer is shown, the indicated airspeed is equal to the true airspeed. The temperature and pressure altitude combinations under which this can occur are shown on scales C and D.

USE OF TRUE AIRSPEED COMPUTER



The navigator's plane is flying at a pressure altitude of 7,000 ft. The temperature is -20° C. and the indicated airspeed is 150 MPH. In the illustration above, the temperature (-20° C.) on scale "C" is shown set opposite 7,000 ft. on scale "D".

The true airspeed (160) is shown on the outer scale "A" opposite the indicated airspeed on scale "B".



In this case, the pressure altitude is 10,000 ft. and the temperature is +10° C. These values are shown set opposite each other on scales "C" and "D".

The indicated airspeed is observed to be 210 MPH. This value is found on scale "B" and opposite, on scale "A" the true airspeed is found to be 250 MPH.

EXAMPLE PROBLEMS

1. The pressure altitude is 5,000 ft. and the temperature is 0° C. The indicated airspeed is 143 MPH. What is the true airspeed?

   ANS: 152 MPH.

2. The pressure altitude is 14,000 ft. and the temperature is -10° C. What is the true airspeed if the indicated airspeed is 182 MPH ?

   ANS: 226 MPH.

3. The pressure altitude is 4,000 ft. and the temperature is +20° C. The indicated airspeed is 138 knots. What is the true airspeed?

   ANS: 149-1/2 knots.

4. The pressure altitude is 11,000 ft. and the temperature is -5° C. The indicated airspeed is 200 kilometers per hour. What is the true airspeed?

   ANS: 236-1/2 kilometers per hour.

CLASSROOM PROBLEMS

1. The pressure altitude is 6400 ft. and the temperature is -7° C. The indicated airspeed is 147 MPH. What is the true airspeed?

   ANS:______________________________

2. The pressure altitude is 3,000 ft. and the temperature is -15° C. The indicated airspeed is 195 MPH. What is the true airspeed?

   ANS:______________________________

3. The pressure altitude is 8,000 ft. and the temperature is +10° C. The indicated airspeed is 161 knots. What is the true airspeed?

   ANS:______________________________

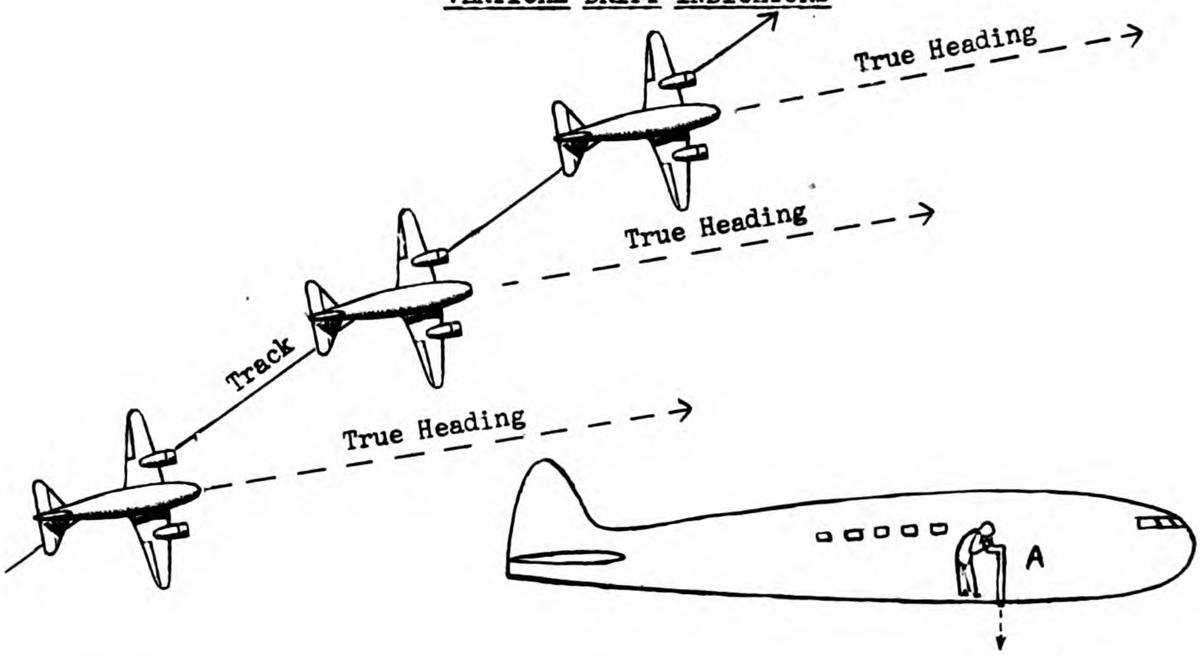
4. The pressure altitude is 24,000 ft. and the temperature is -25° C. The indicated airspeed is 224 knots. What is the true airspeed?

   ANS:______________________________

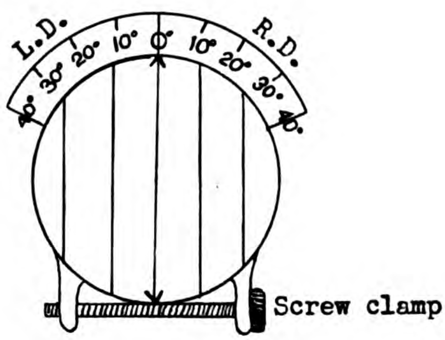
5. In problem 3 above, suppose you read your altimeter 1,000 ft. wrong. What would the true airspeed have been if your pressure altitude had really been 7,000 ft.?

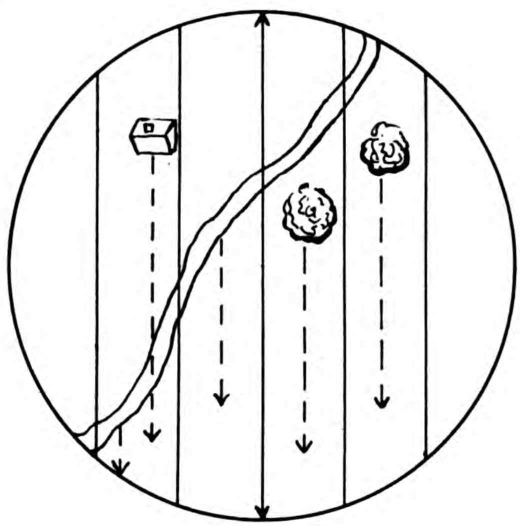
   ANS:______________________________

VERTICAL DRIFT INDICATORS



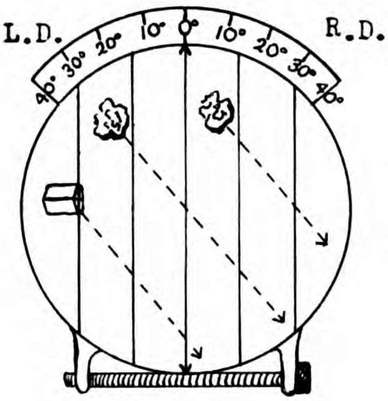
The track usually differs from the true heading. When the surface of the earth is visible the navigator determines this difference by looking vertically downward through a drift indicator as at "A".

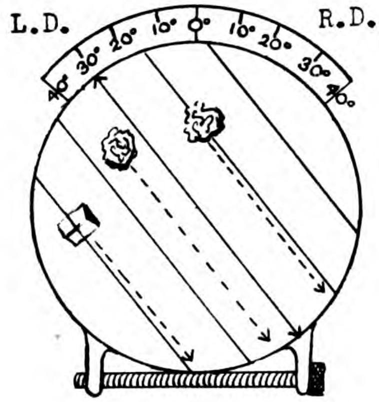




The figure at the left is a detailed view of the top of the drift indicator. Notice the left drift and right drift markings.

The figure at the right shows what the navigator sees when looking down at the countryside. The dotted lines show the line of movement of prominent objects when there is no drift.





The figure at the left shows how prominent objects appear to move when the plane is drifting left.

The figure at the right shows how the top of the drift indicator is turned in order to ascertain the amount of drift. In this case the plane is drifting 30° left.

EXAMPLE PROBLEMS

1. How much of the surface of the earth can be seen in the vertical drift indicator?

   ANS: The amount seen depends on your altitude. If low, you will see about one hundred yards; if high, you may see two miles of the surface.

2. About how long will objects remain in the field of vision?

   ANS: This depends on your speed and altitude. If low, objects may disappear in a few seconds; if high, they may be visible thirty or forty seconds.

3. If your true heading is 300° and you observe 14° right drift, what track are you making?

   ANS: 314° true.

4. How long do white-caps remain well defined?

   ANS: Small white-caps disappear almost immediately after forming. Large white-caps remain sharply defined for as much as 20 seconds.

5. Do white-caps move across the surface of the sea?

   ANS: On a beach where the water is actually in motion, the white-caps move with the water. In the open sea, the swell passes underneath the white-caps and leaves them behind.

CLASSROOM PROBLEMS

1. You are steering 056° by compass. The compass error is 21° W. and the drift is 8° R. What track are you making?

   ANS: ____________________

2. You are steering 218° by compass. The compass error is 13° E. and the drift is 4° R. What track are you making?

   ANS: ____________________

3. You are steering 356° by compass. The compass error is 6° E. and the drift is 3° L. What track are you making?

   ANS: ____________________

4. You are steering 272° by compass. The variation is 24° W., the deviation is 6° E. and the drift is 9° R. What track are you making?

   ANS: ____________________

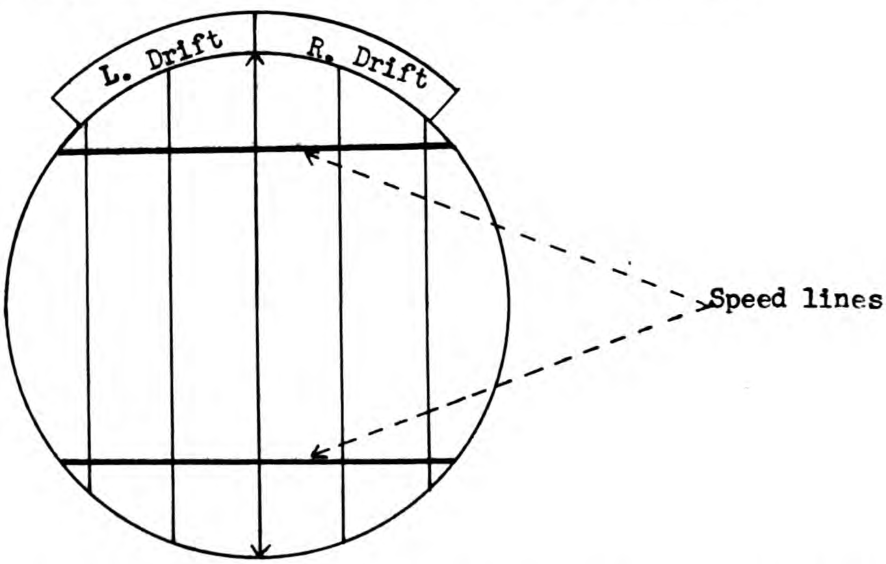
5. You are maintaining a magnetic heading of 042°. The variation is 3° E. and the drift is 3° L. What track are you making?

   ANS: ____________________

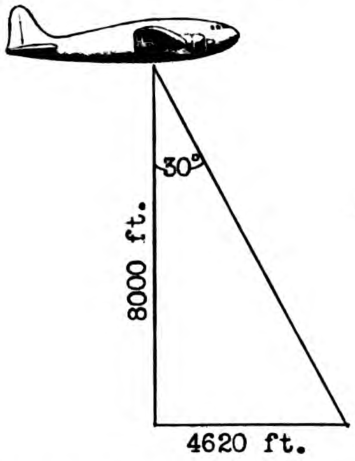
6. If you observe 15° drift when heading 090° true, would you expect to allow for a 15° drift on every other heading?

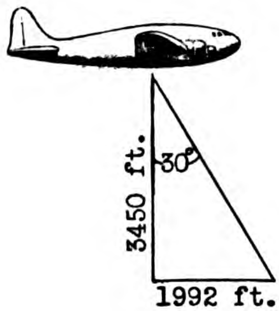
   ANS: ____________________

DETERMINATION OF GROUNDSPEED WITH VERTICAL DRIFT INDICATORS



Some vertical drift indicators are equipped with so-called "speed-lines" as shown in the illustration above. When the navigator looks down through the drift indicator, he sees an area included between these lines that varies in size according to his altitude and spacing of these lines.





For any given altitude the distance seen on the surface may readily be calculated. In the diagram at the left the navigator is looking down through a drift indicator that gives him a 30° field of vision between the speed-lines. At an altitude of 8,000 ft. he sees 4,619.6 ft. of the earth between the speed-lines.

In the diagram at the right the plane is at an altitude of 3,450 ft. At this altitude the navigator sees 1,991.96 ft. of the earth between the speed-lines.

The formula used was: Groundspeed = Height x tan 30°.

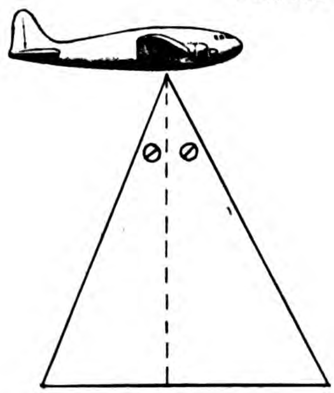
The time required to pass over an object first sighted some distance ahead depends on the groundspeed of the plane. If the time interval is carefully determined by means of a stop watch, the groundspeed may be determined.

When the instrument is designed to include spread of 30° between the speed-lines as <u>shown</u>, the following formulas may be used:

$$\underset{\text{(knots)}}{\text{Groundspeed}} = \frac{\text{Height in feet} \times .3419}{\text{Time (in seconds)}} \qquad \underset{\text{(MPH)}}{\text{Groundspeed}} = \frac{\text{Height in feet} \times .3936}{\text{Time (in seconds)}}$$

The factors .3419 and .3936 are for knots and miles per hour respectively. They were computed from the following formulas:

$$\text{Factor} = \frac{3600 \tan \theta}{6080} \qquad \text{Factor} = \frac{3600 \tan \theta}{5280}$$



In the event the field of vision is similar to that shown above, the factors can be computed for each triangle and their <u>sum</u> <u>used</u>.

EXAMPLE PROBLEMS

1. When you sight between the speed-lines of your vertical drift indicator your field of vision extends from 15° ahead to 10° back of the vertical. What factor should be used in the equation?

$$\text{Groundspeed in knots} = \frac{\text{H x Factor}}{\text{Seconds}}$$

ANS: .2630

2. In timing the passage of prominent objects between the speed-lines, should you time more than one or is this sufficient to give you an accurate check on your groundspeed?

ANS: Time the passage of ten prominent objects and average the ten times.

3. Is it important to know your precise altitude?

ANS: It is <u>very</u> important.

CLASSROOM PROBLEMS

1. When looking down through your drift indicator, your field of vision between speed-lines extends 20° forward and 10° back from the vertical. What factor is to be used to determine groundspeed with this instrument?

The tangent of 10° is .17633
The tangent of 20° is .36397
The tangent of 30° is .57735

ANS: ____________________

2. The groundspeed factor for your drift indicator is .3419 for knots. You time the passage of 10 prominent trees and the average of these times is 11.6 seconds. Your correct altitude is 7,600 ft. What is the groundspeed?

ANS: ____________________

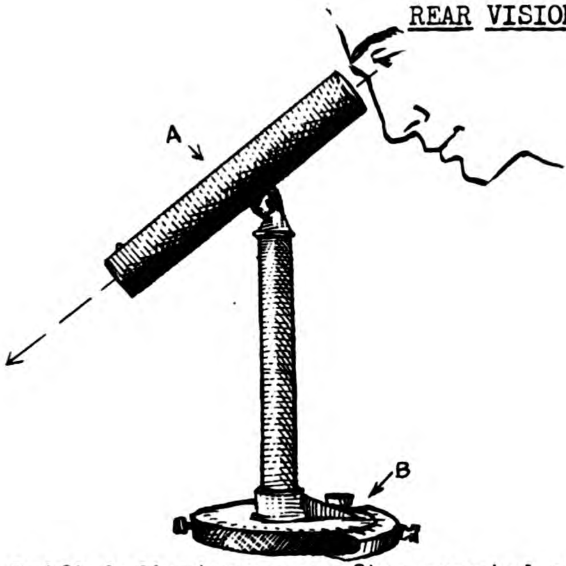
3. The groundspeed factor for your drift indicator is .3419 for knots. The average time of passage for ten prominent white-caps is 14.3 seconds. The indicated altitude above sea level pressure is 12,000 ft. and the outside temperature is 0° C. What is the groundspeed?

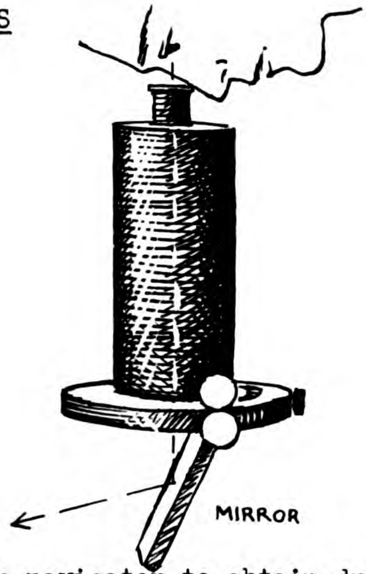
ANS: ____________________

4. The groundspeed factor for your drift indicator is .2199 for knots. At an indicated altitude of 6,500 ft. (temp. -5° C.) the average time of passage for ten prominent white-caps is 14.1 seconds. What is the groundspeed?

ANS: ____________________

REAR VISION DRIFT INDICATORS





Drift indicators are often mounted so as to enable the navigator to obtain drift by looking back at float lights or other objects thrown overboard from the plane.

Two such instruments are shown above. While they differ in construction, their function in determining drift is the same. When used for this purpose, the sighting device such as "A" is depressed and the unit is turned left or right until the float light is seen.

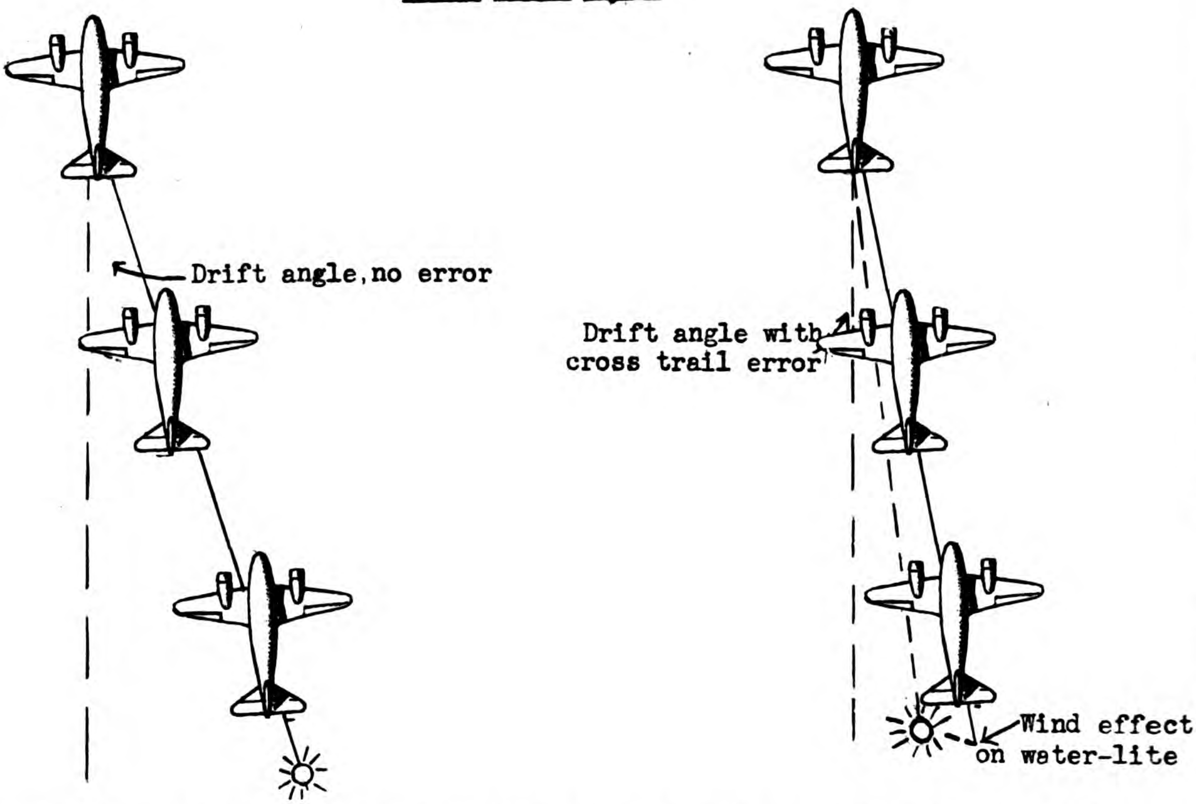
The drift angle is then read on scale "B". The amount of drift shown on scale "B" depends on the amount the sighting device had to be turned to pick up the float light.

The field of vision can be changed at will by raising or lowering the sighting piece. Because of this necessary characteristic, such instruments cannot be used for groundspeed determination.

DRIFT LIGHT

The drift light shown above weighs about a pound. The navigator throws it overboard from the plane and, on hitting the surface of the sea, it ignites. It burns brilliantly and emits considerable smoke for a period of several minutes.

CROSS-TRAIL ERROR

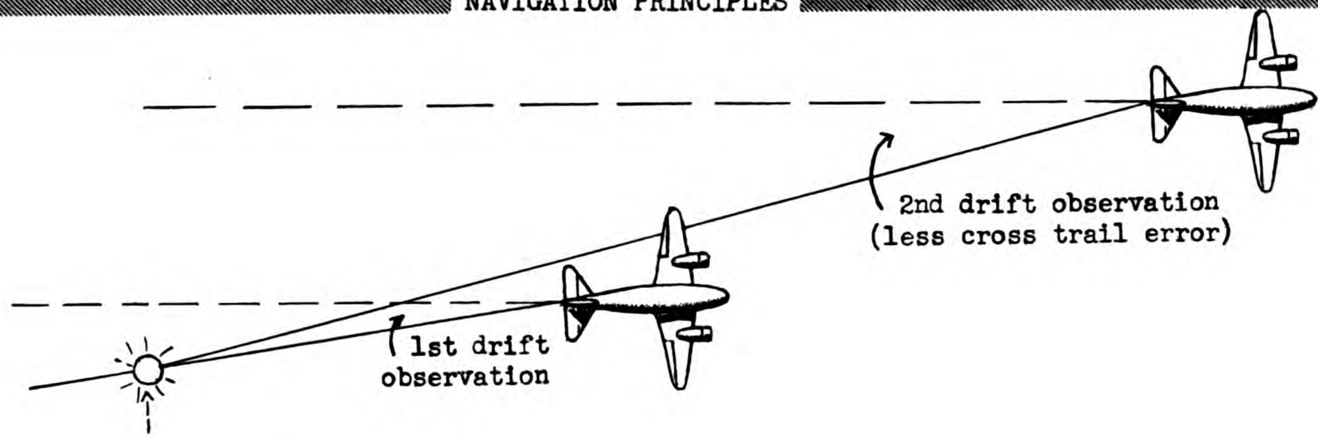


Unless the water light is thrown overboard close to the surface, the wind will act on it for a considerable period of time depending on the altitude of the plane.

This produces an error called "cross-trail" error in the observed drift because the water light comes to rest on the sea at a place over which the plane never passed.

In the diagrams above two planes are shown flying in the same wind. The plane at the left is close to the surface while the one at the right is high up.

The navigators of these planes throw water lights over at the same time. There is little if any error in the drift as observed from the low plane at the left. The water light from the high plane at the right drifted with the wind on the way down, resulting in "cross-trail" error in the drift observation.



Cross-trail error can be reduced by delaying the actual drift observation until the lateral drift of the water light becomes of small importance when compared with the distance of the plane from the light.

EXAMPLE PROBLEMS

1. Your magnetic heading at Boston is 132°. You observe 14° right drift. What track are you making good?

   ANS: 131° true.

2. You are steering 206° by compass. The total error of the compass is 18° east. You observe 3° left drift. What track are you making good?

   ANS: 221° true.

3. Your compass heading is 309°. The variation is 6° W. and the deviation is 7° E. The drift is 11° left. What track are you making good?

   ANS: 299° true.

CLASSROOM PROBLEMS

1. Does cross-trail error occur in vertical drift observations? Explain.

   ANS:____________________

2. You are heading 052° by compass. The variation is 14° E., the deviation is 4° E. and the drift is 11° right. What track are you making good?

   ANS:____________________

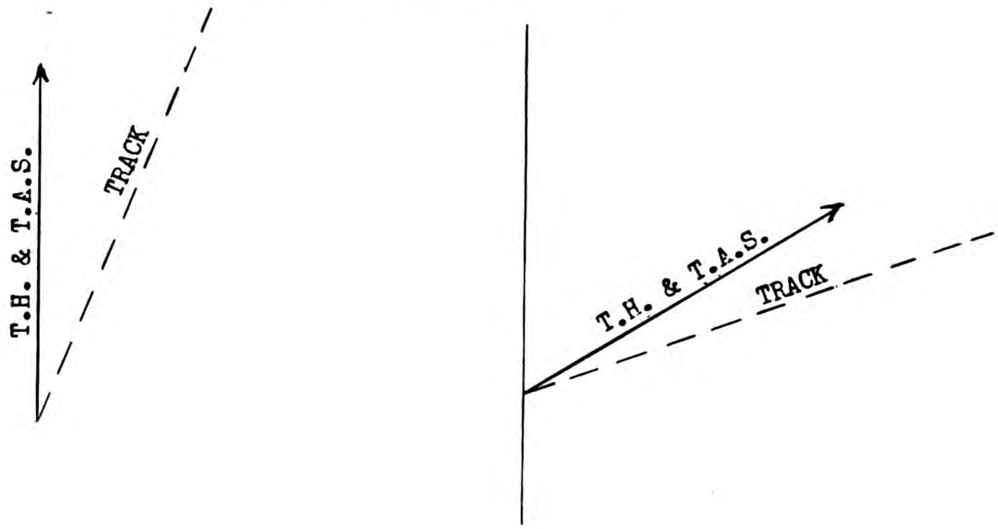
3. You are headed 001° true and the drift is 12° left. What track are you making good?

   ANS:____________________

4. Your magnetic heading is 182° and the variation is 16° W. The drift is 3° right. What track are you making good?

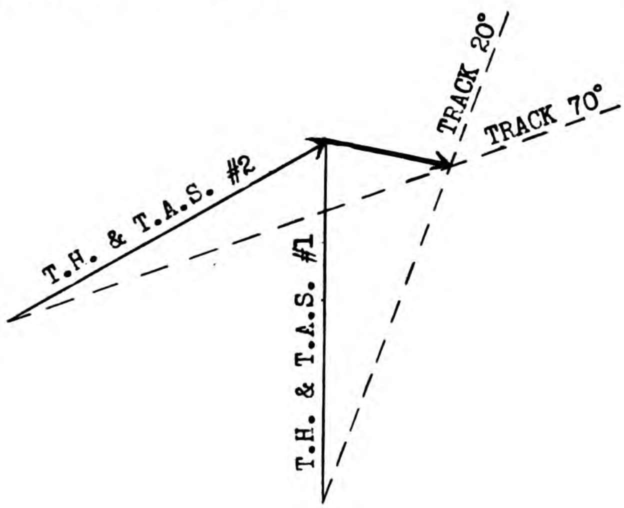
ANS:____

USE OF DRIFT TO DETERMINE WIND



A single drift observation does not supply enough information to enable the navigator to determine the wind. In the diagram above at the left, a plane is shown heading 000° true and drifting 20° right. This only proves that the wind is blowing from somewhere in the west.

In the diagram at the right the same plane is shown headed 060° true in the same wind and drifting 10° right. This fact, likewise, is insufficient by itself to enable the navigator to find the wind.



When the results of both drift observations are super-imposed on each other as shown above, there is enough information available to enable the navigator to de-

termine wind direction and velocity.

According to the first observation, the plane had to be somewhere on track 020° when headed true north. According to the second observation, the plane had to be somewhere on track 070° when headed 060° in the same wind.

The arrangement of the two problems as above shows that only the intersection of the track lines satisfies both these requirements.

The arrow shows the only wind that could have caused both of these drifts. If the problem is drawn on an hourly basis, the length of the wind arrow represents the hourly velocity of the wind. The direction of the wind arrow shows the direction of the wind.

EXAMPLE PROBLEMS

1. Does the plane have to circle back in order to enable the navigator to make a second drift run at the same place he made the first?

   ANS: No. After the first drift observation is made, the plane is headed from 45° to 90° left or right of the first heading and the second drift is taken. When plotted, the results are so placed that the plane appears to have turned back and headed each time for the same spot.

2. Is it sufficient to take just two drift observations?

   ANS: Another drift is often taken on a third heading to check the results of the first two.

3. On a true heading 270° by compass, the variation is 15° west and the deviation is 3° west. You observe 3° left drift. True airspeed is 172 MPH. On heading 350° by compass (deviation 2° east) you observe 15° right drift. What is the wind direction and velocity?

   ANS: The wind is from 262°-43 MPH.

CLASSROOM PROBLEMS

1. Your indicated altitude is 9,000 ft., indicated airspeed 144 knots, and temperature 0° C.

   On compass heading 210° (Var. 20° west, Dev. 5° west) you observe 6° left drift.

   On compass heading 158° (Dev. 2° west) you observe 8° left drift. What is the wind direction and velocity?

   ANS:____

2. Your indicated altitude is 4,000 ft., indicated airspeed 122 knots and temperature 10° C.

On compass heading 303° (Var. 15° east, Dev. 2° west) you observe 11° left drift.

On compass heading 210° (Dev. 2° east) you observe 7° right drift. What is the wind direction and velocity?

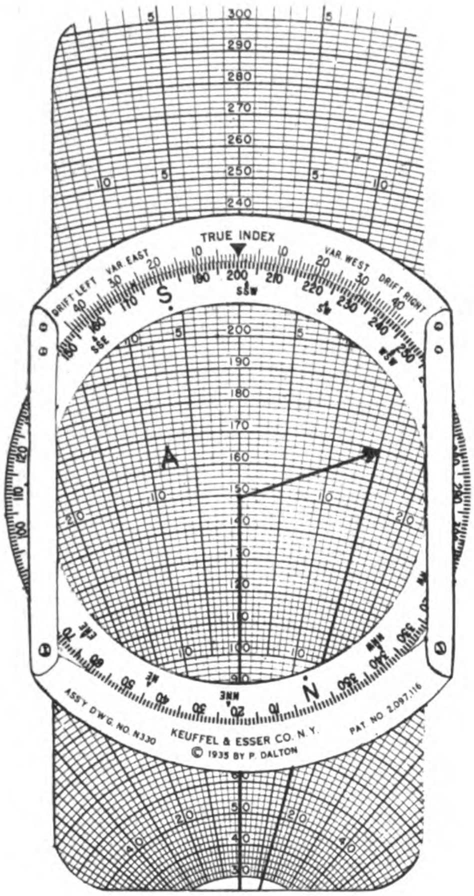
ANS:____

3. On true heading 066° you observe 13° left drift. On true heading 343° you observe 11° left drift. Your true airspeed is 141 MPH. What is the wind direction and velocity?

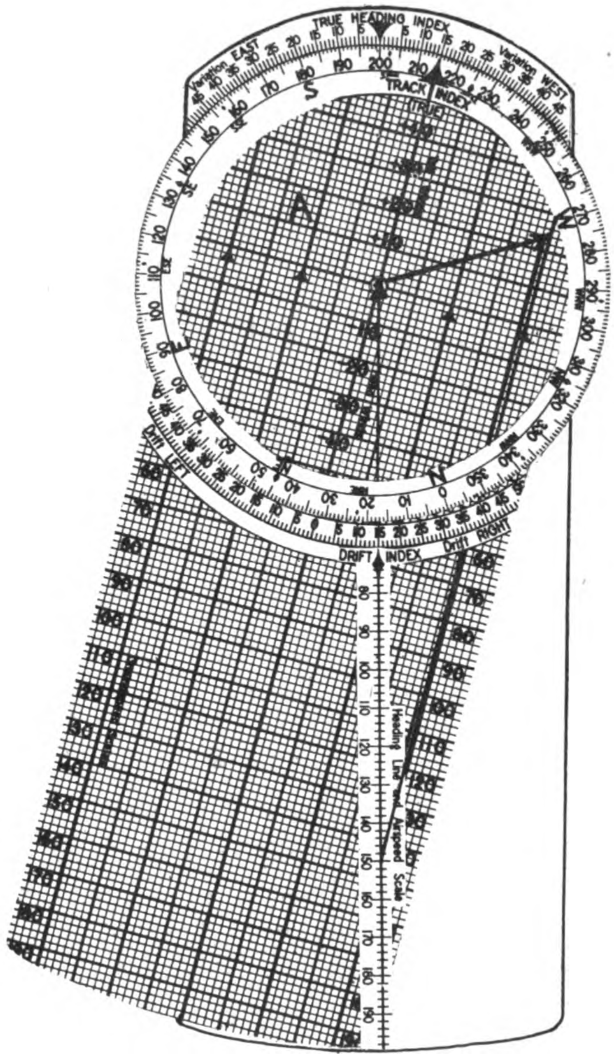
ANS:____

USE OF COMPUTERS FOR SOLUTION OF TRIANGLE OF VELOCITIES

CASE 1 (Given T.H. & T.A.S. Track & G.S. - - Find the wind) CASE 1



DALTON MODEL J



DALTON MK VII

The use of either of the navigational computers shown above will speed up the solution of problems involving the triangle of velocities.

A true heading of 200° and a track of 215° has been drawn on each. The true airspeed (length of the true heading line) is 150 miles; the ground speed (length of the track line) is 170 miles.

If this information is known to the navigator, it becomes possible to close the triangle of velocities and find the wind.

The wind blows from the true heading line towards the track line; i.e., from left to right in this case. Its force and direction can be found by rotating

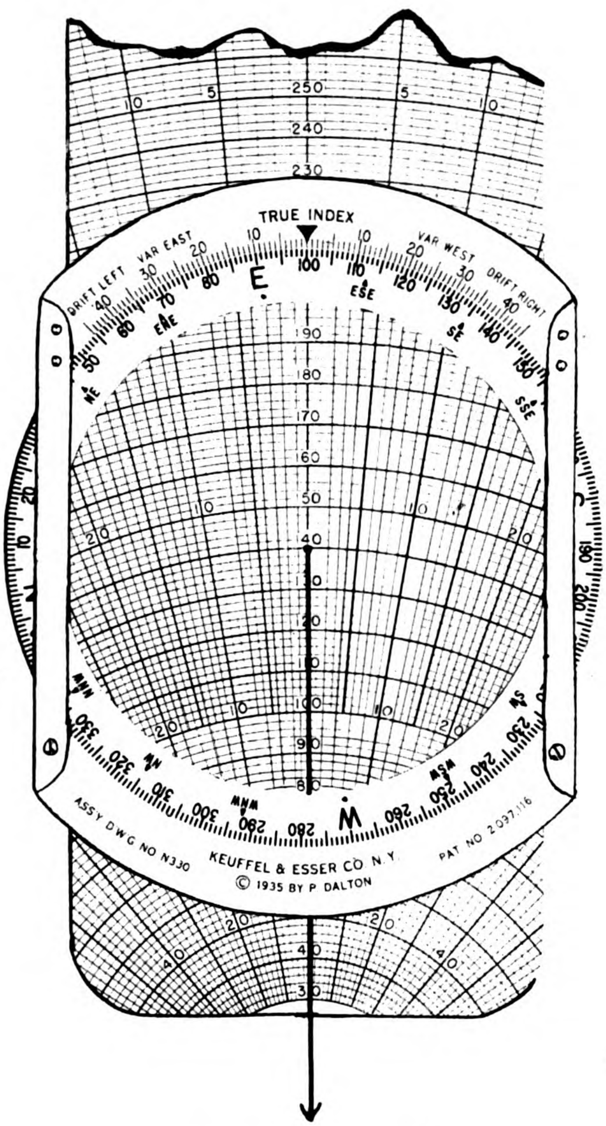
the disk "A" until the wind arrow points vertically downward. The direction appearing at the true index then shows the direction of the wind and the velocity may be measured on the computer scale.

In the problem above, the wind is from 93° velocity, 48 miles per hour.

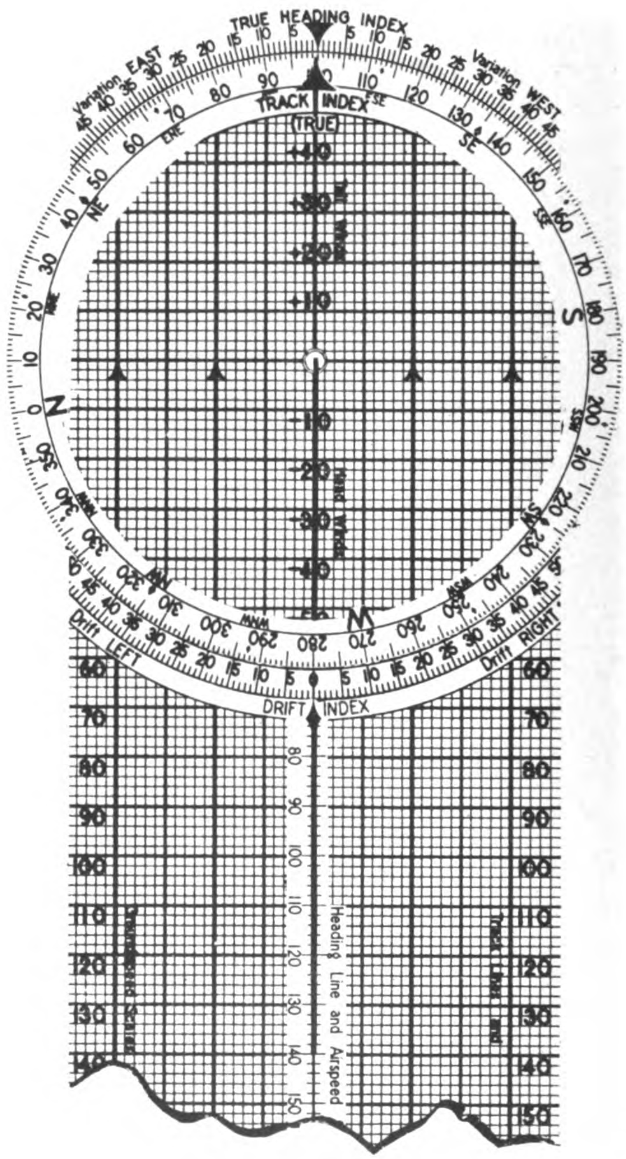
EXAMPLE PROBLEMS

1. Show a true heading of 100° and a true airspeed of 140 MPH.

ANS:

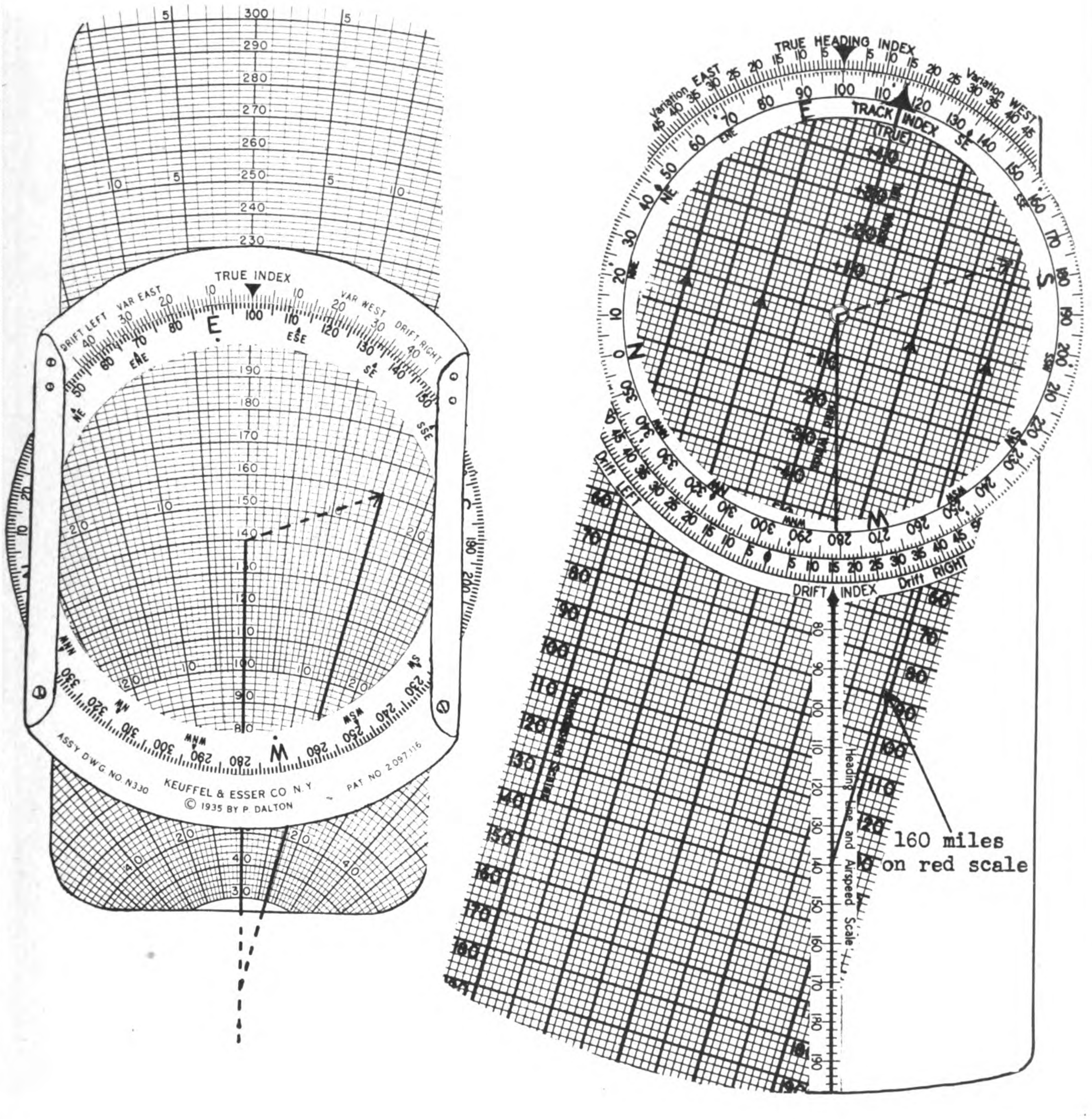


To zero airspeed



2. In addition to the true heading and airspeed, show a track of 115° and a groundspeed of 160 MPH. Show the wind as a dotted line.

ANS:



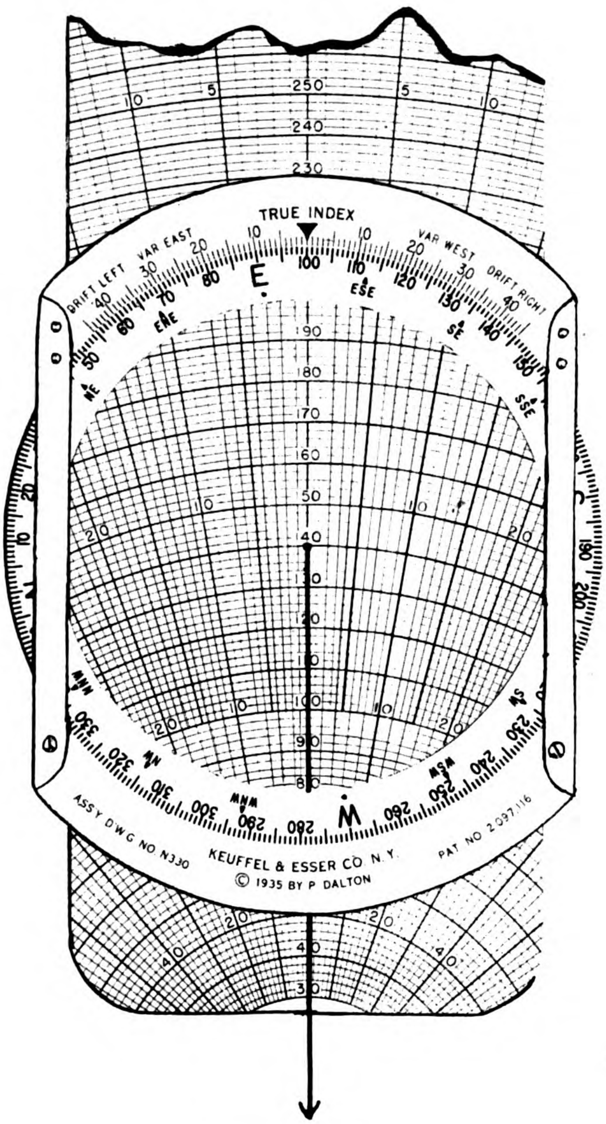
the disk "A" until the wind arrow points vertically downward. The direction appearing at the true index then shows the direction of the wind and the velocity may be measured on the computer scale.

In the problem above, the wind is from 93° velocity, 48 miles per hour.

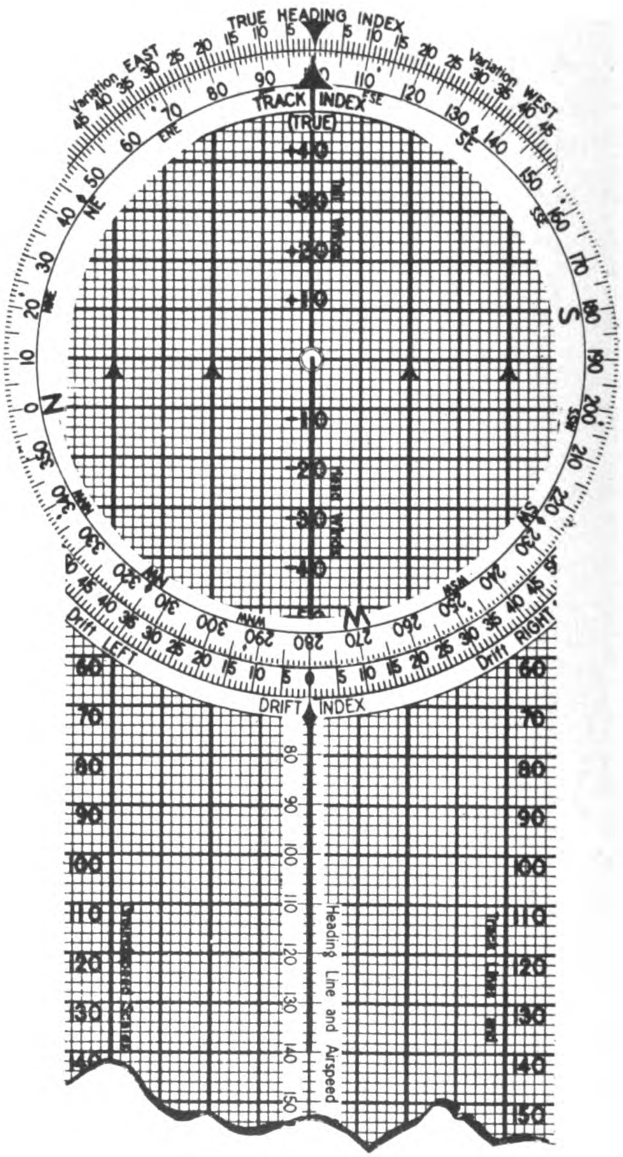
EXAMPLE PROBLEMS

1. Show a true heading of 100° and a true airspeed of 140 MPH.

ANS:

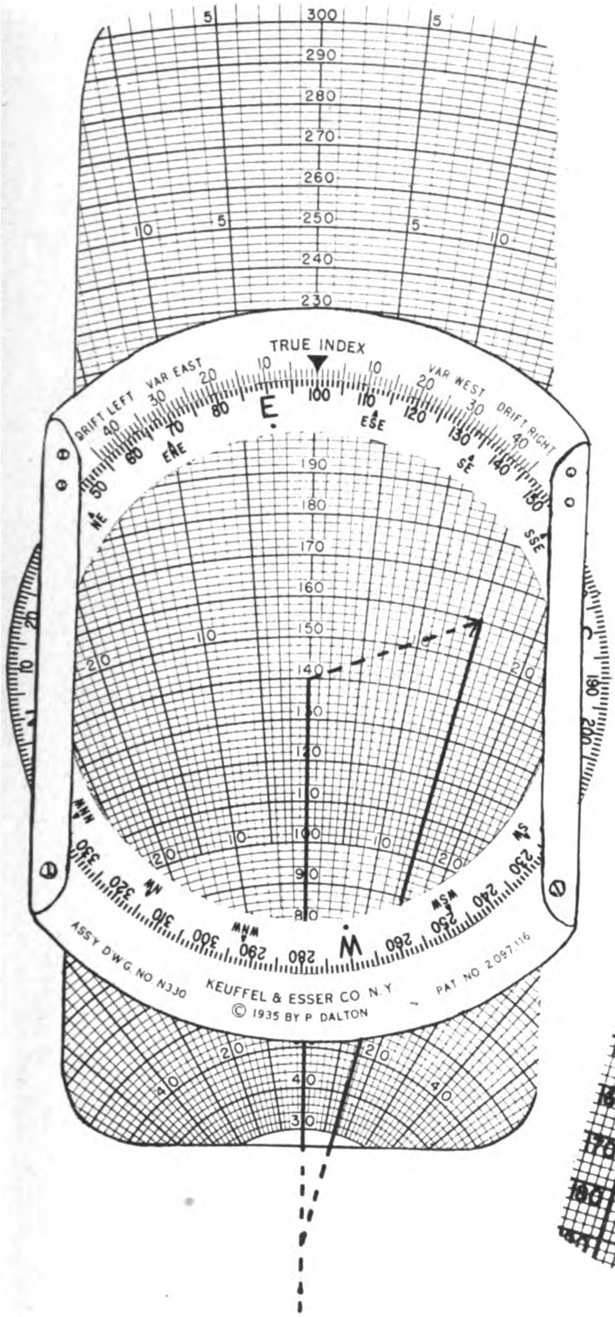


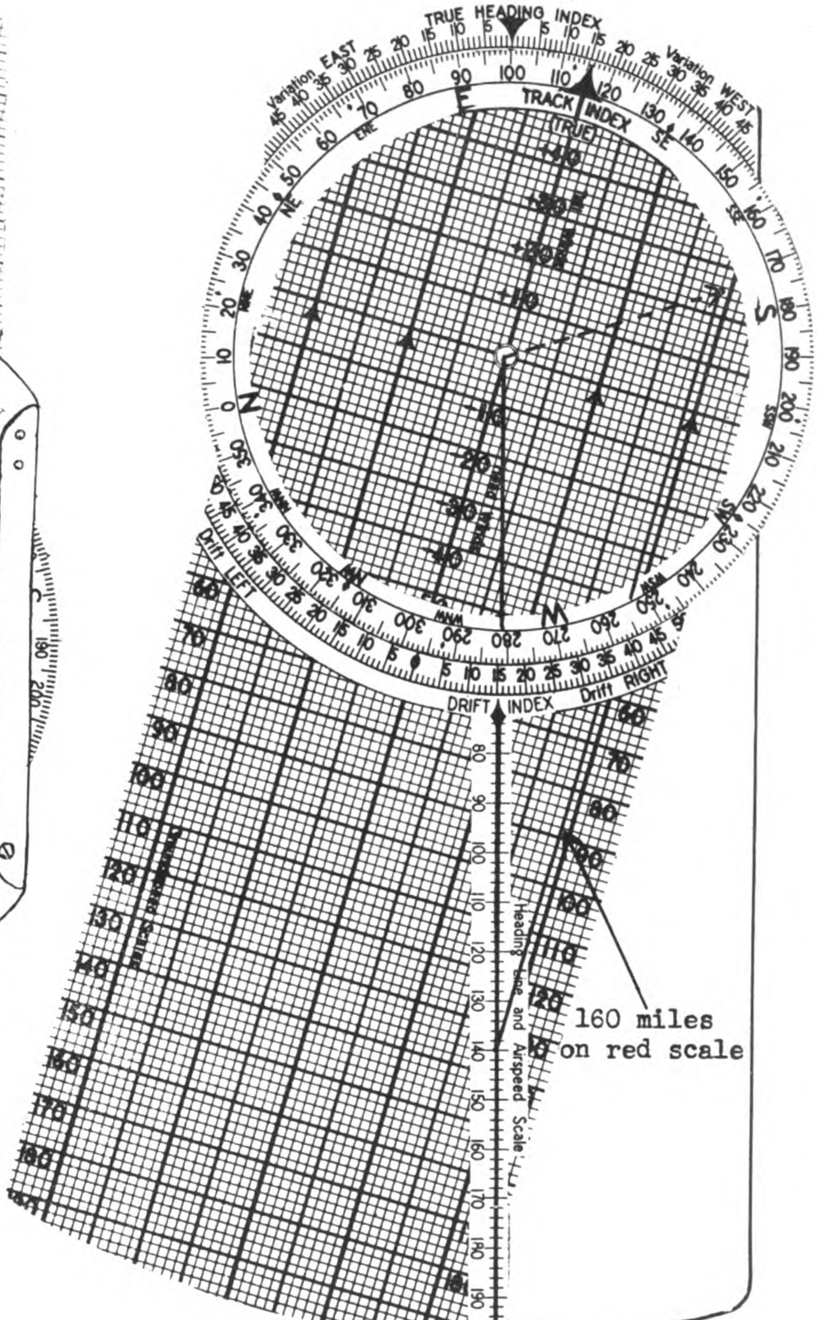
To zero airspeed



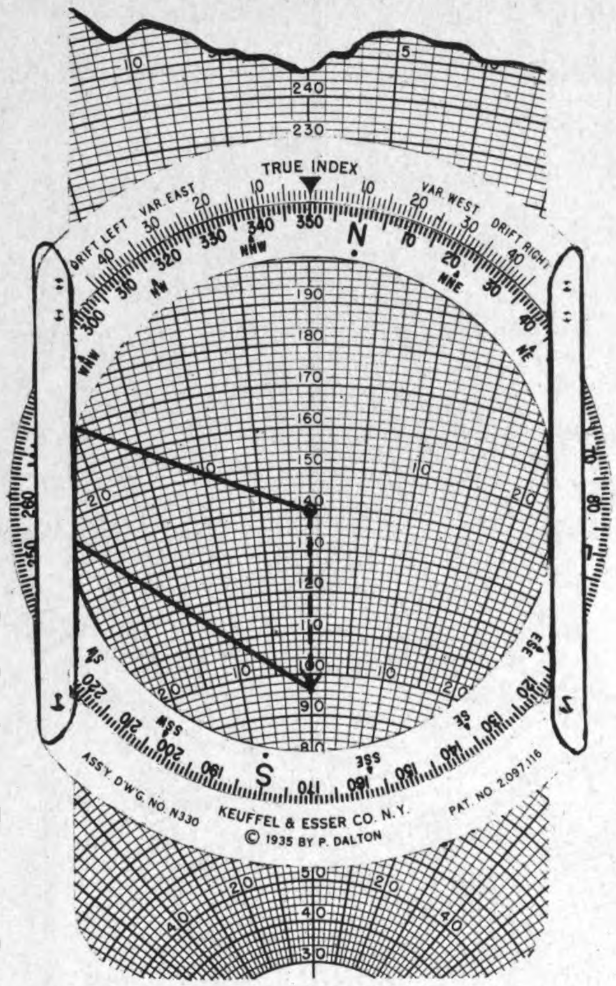
2. In addition to the true heading and airspeed, show a track of 115° and a groundspeed of 160 MPH. Show the wind as a dotted line.

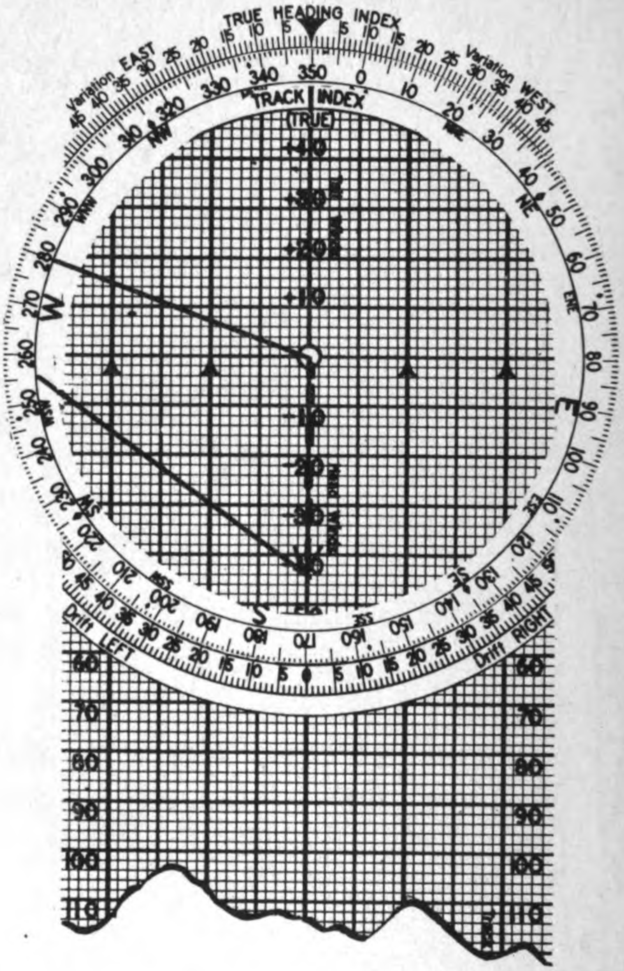
ANS:





3. Rotate the circular disk until the wind arrow points vertically downward and determine the wind.





ANS: The wind is from 350° and the velocity is 44 MPH.

CLASSROOM PROBLEMS

(Use Dalton Model J, Mark VII or the equivalent)

1. What wind has been acting on your plane if you maintained a true heading of 035° and a true airspeed of 150 MPH but made a track of 043° and a groundspeed of 144 MPH?

ANS: ____

2. What wind has been acting on your plane if you have made a track of 345° and a groundspeed of 163 MPH while maintaining a true heading of 355° and a true airspeed of 160 MPH?

ANS: ____

3. What wind has been acting on your plane if you have made a track of 260° and a groundspeed of 170 knots while maintaining a true heading of 247° and a true airspeed of 156 knots?

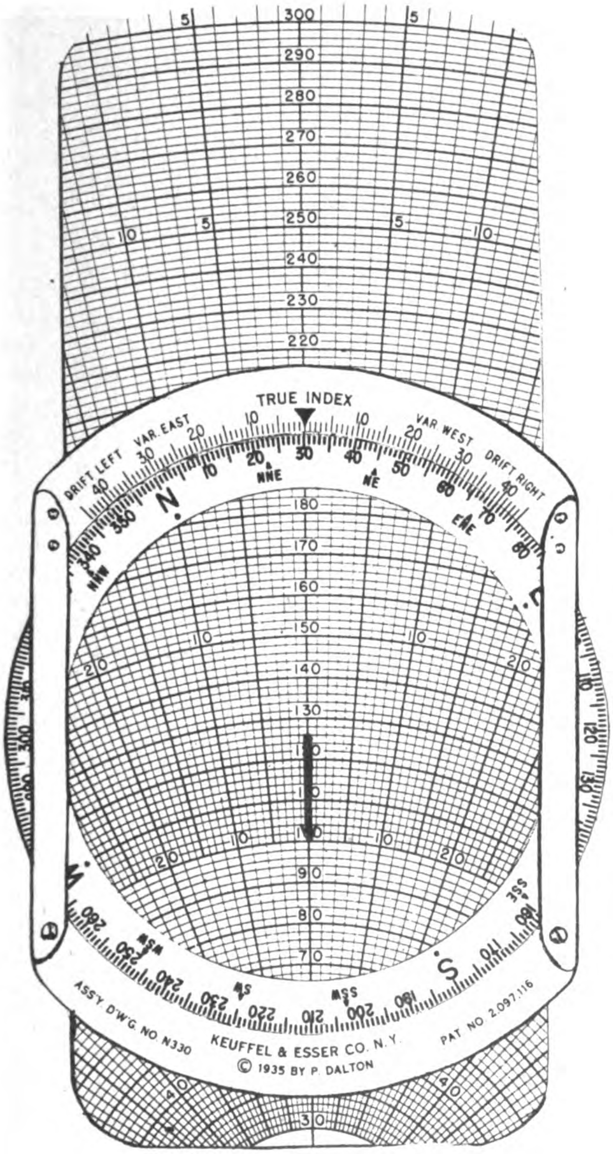
ANS: ____

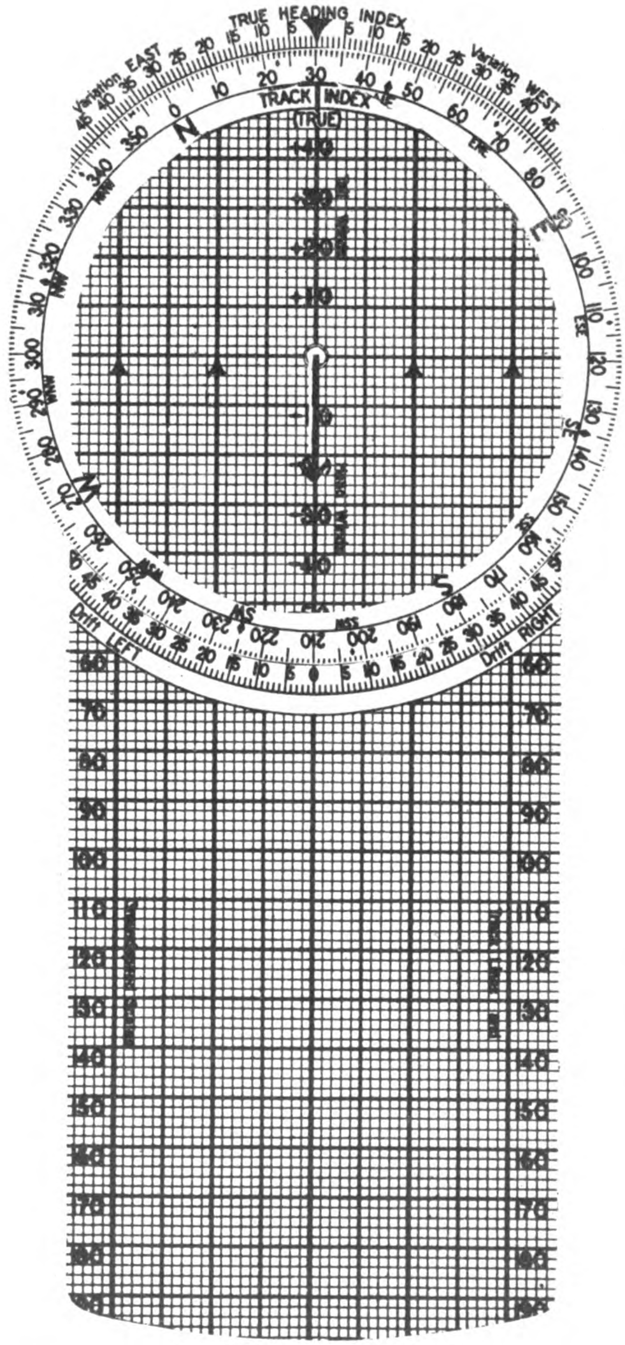
EXAMPLE PROBLEMS

CASE 2 (Given T.H. & T.A.S., Wind direction & Velocity - - Find Track & G.S.) CASE 2

1. Draw in a wind of 030°-25 knots on the Model J and Mark VII computers.

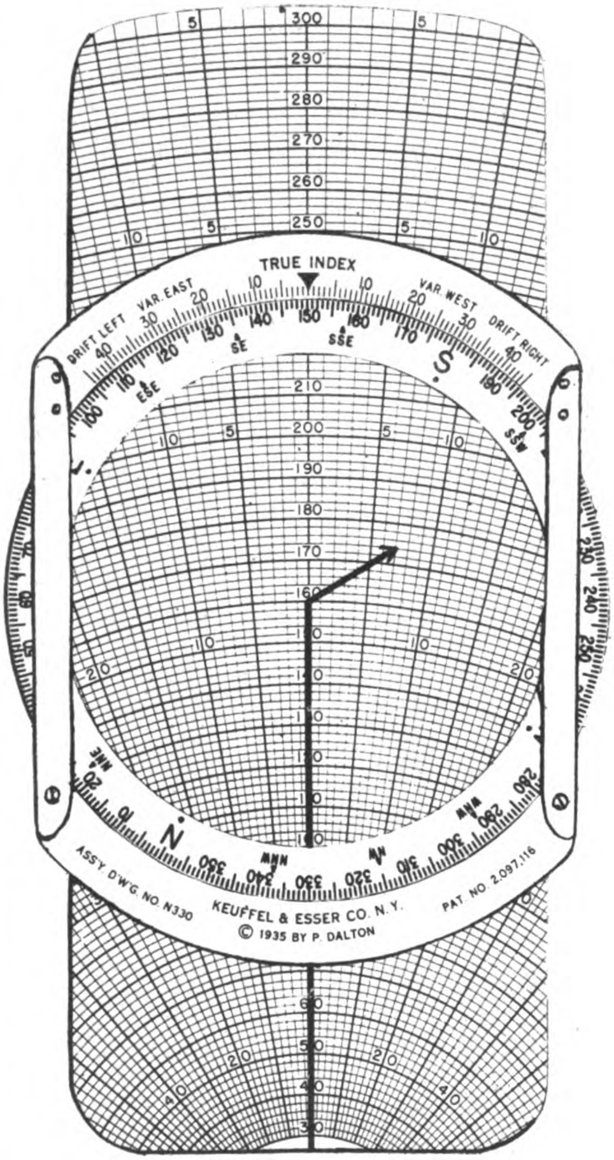
ANS:

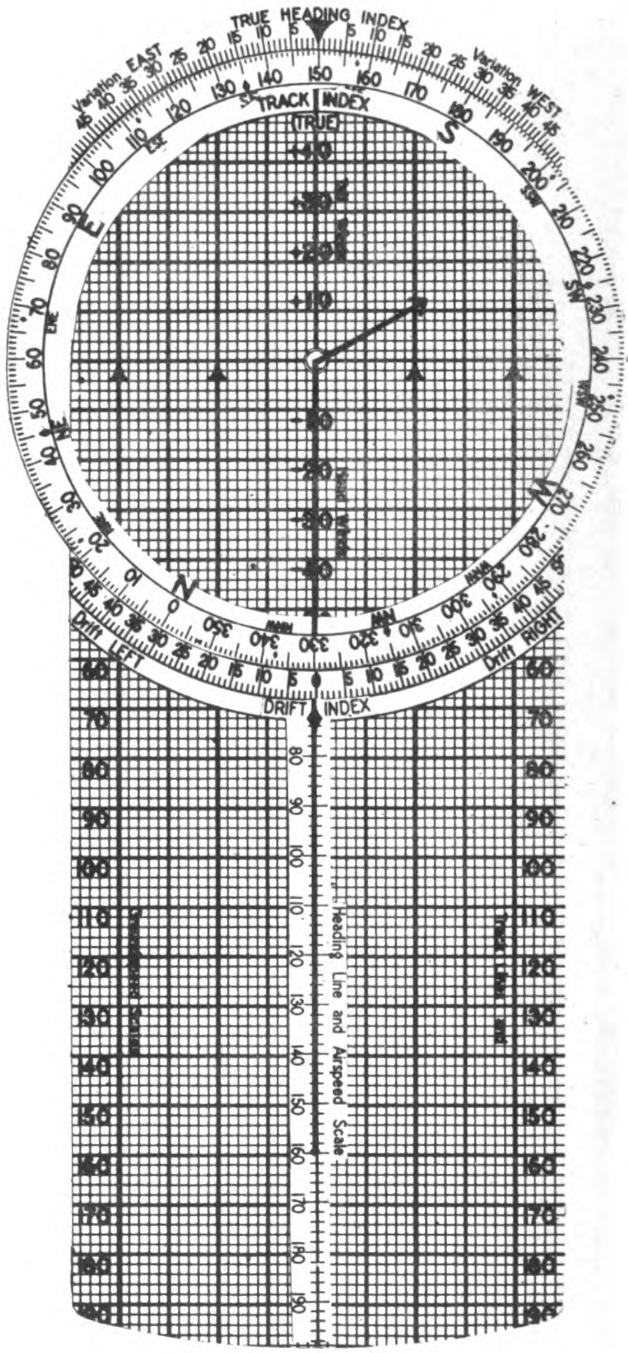




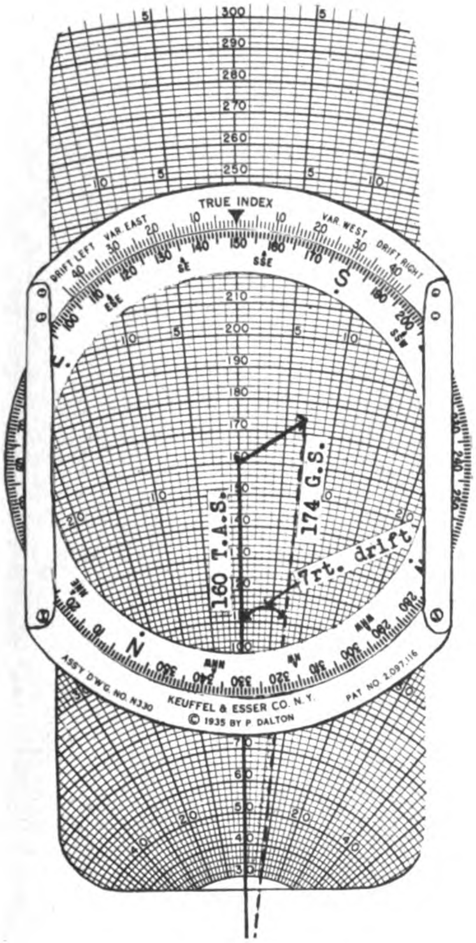
2. **Draw (in addition to the wind) a true heading of 150° and show an airspeed of 160 knots.**

ANS:

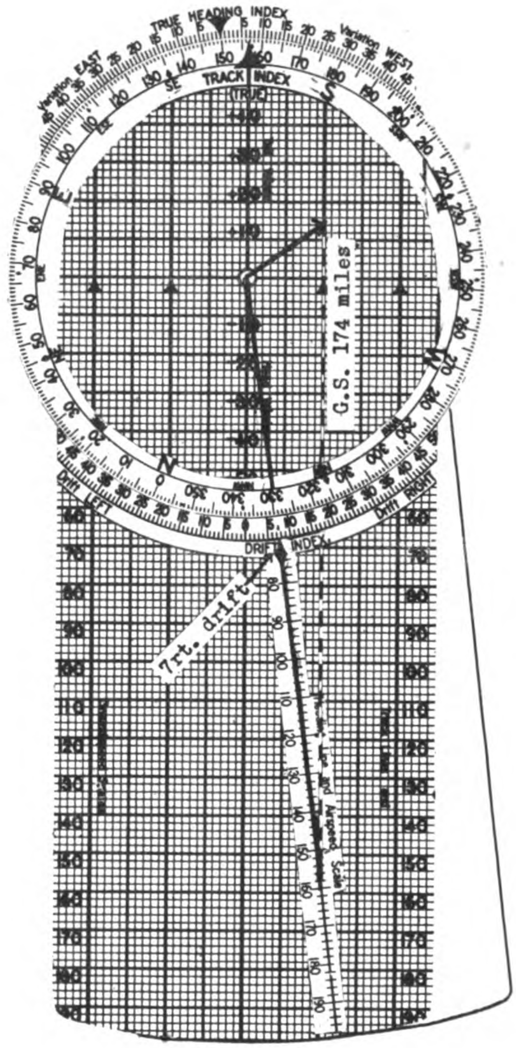




3. Show the completed triangle of velocities. What drift track and groundspeed result from this condition of wind, heading and airspeed?



to zero



CLASSROOM PROBLEMS

(Use Model J or Mark VII or equivalent computer)

1. Show the following combinations of wind, true heading and true airspeed.

Wind	True Heading	True Airspeed
060 - 40 MPH	040	120 MPH
310 - 15 MPH	175	185 MPH
210 - 37 MPH	275	136 MPH

2. Show the following combination of wind, true heading and true airspeed.

Wind	True Heading	True Airspeed
080 - 32 kts.	080	162 kts.

What track and groundspeed will be made under this flight condition?

ANS: ______________________________

3. What track and groundspeed will be made under the following flight conditions? Wind 180°-25 kts. T.H. 315°. T.A.S. 144 kts.

   ANS:____

4. You are heading 049° true and the true airspeed is 162 kts. The wind is 255°-18 kts. What track and groundspeed are you making?

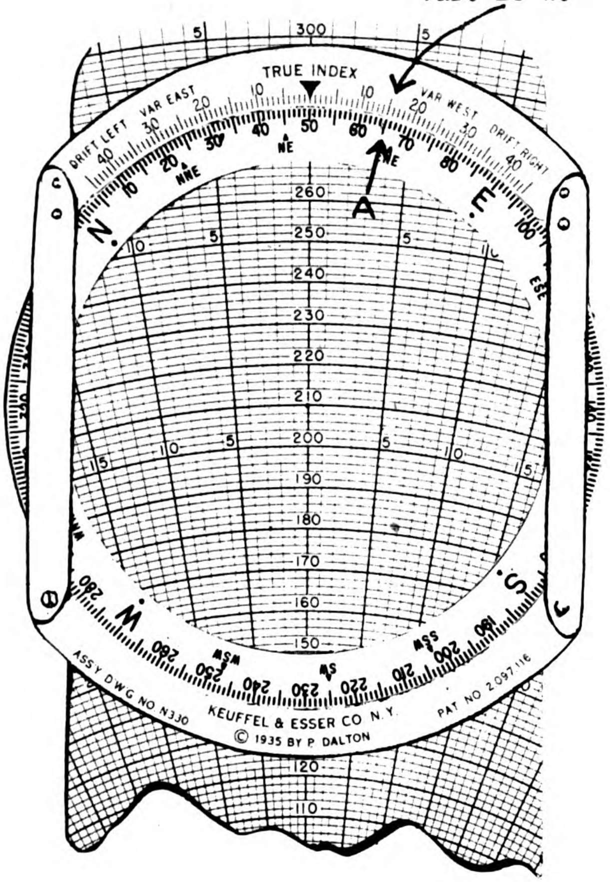
   ANS:____

5. You are heading 117° true and the true airspeed is 126 kts. The wind is 090°-32 kts. What track and groundspeed are you making?

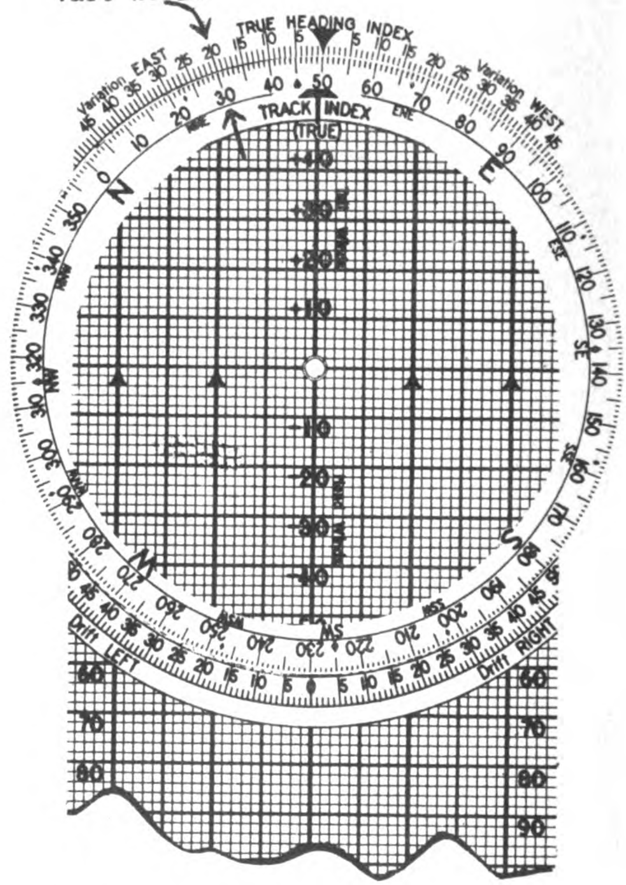
   ANS:____

USE OF VARIATION SCALE

Var. 15° W.



Var. 20° E.

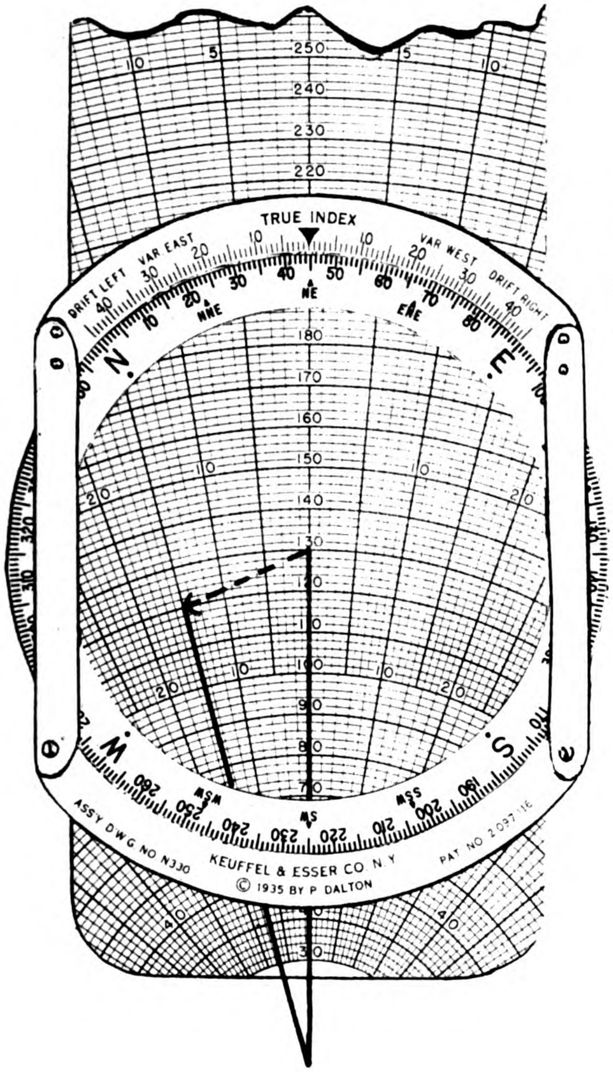


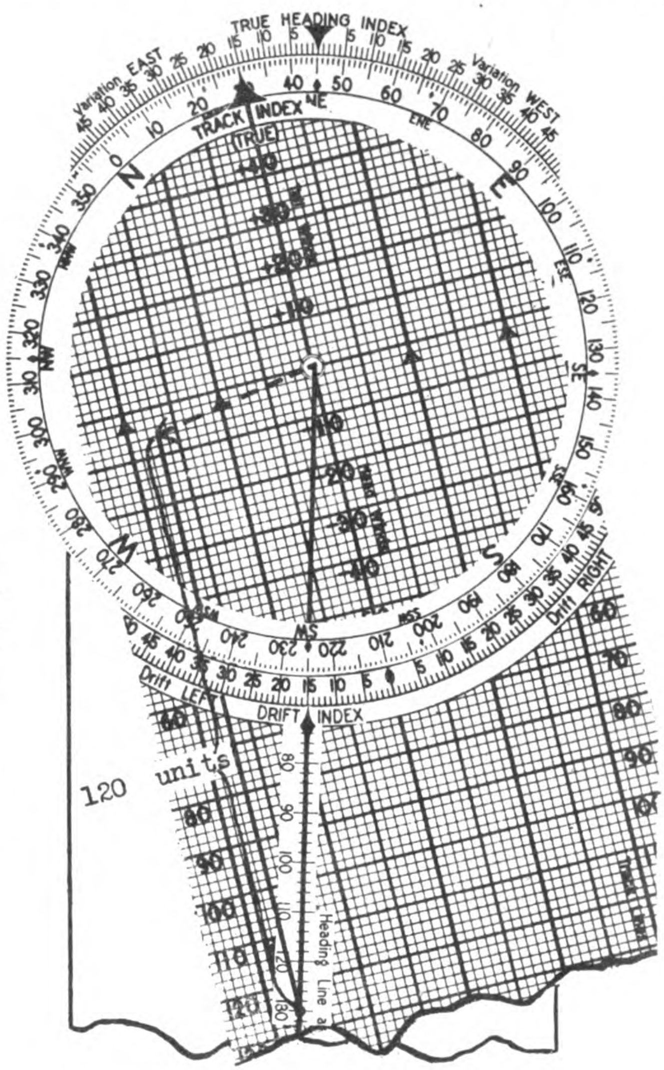
In the illustration at the left, a true heading of 050° is shown properly set opposite the true (heading) index. If the variation is 15° west, this is equivalent to a magnetic heading of 065°. See "A" above.

In the illustration to the right, the true heading is still 050° but the variation is 20° east. This is equivalent to a magnetic heading of 030°.

In working problems on the computer, the navigator will save mental arithmetic by setting the magnetic heading opposite the proper variation. If this is done, the true heading will automatically fall opposite the true index.

CASE 3 (Given T.H. & T.A.S., Drift & G.S. - - find wind direction and velocity) CASE 3





When the above information is available (as for example through the use of the vertical drift indicator), the wind now acting on the plane can be determined. After the true heading and airspeed have been set on the computer, the drift is applied and the track obtained. Groundspeed is always measured along the track.

In the diagrams above, the T.H. is 45°, the T.A.S. is 130 kts., the drift is 15° left and the G.S. is 120 kts.

The wind is shown by the dotted line, 111°-35 kts.

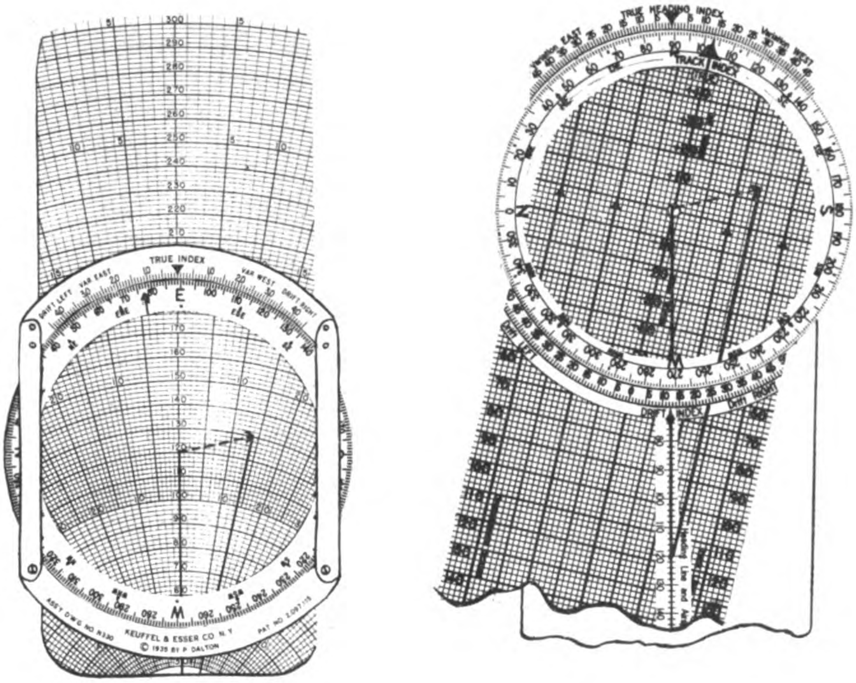
EXAMPLE PROBLEM

1. You are maintaining a magnetic heading of 77° where the variation is 12° east. Your true airspeed is 120 kts. The observed drift is 14° right and the timed groundspeed is 130 kts.

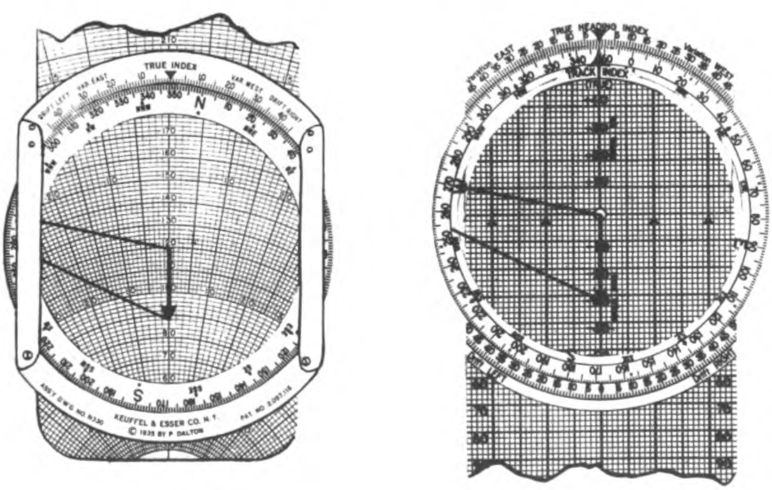
   Show this problem on both computers.

   What is the wind direction and velocity acting on the plane?

   ANS:



The problem is illustrated above on both the Model J and Mark VII computers.



The method of measuring the wind direction and velocity is shown above. The wind is 348°-32 kts.

CLASSROOM PROBLEMS

1. You are maintaining a magnetic heading of 033° where the variation is 11° east. The true airspeed is 152 kts. The observed drift is 4° right and the timed groundspeed is 165 kts.

   What wind is acting on the plane?

   ANS: ____________________

2. You are flying at 7500 ft. indicated altitude where the temperature is -10° C. The indicated airspeed is 126 kts. The compass heading is 247°, the variation is 7° west and the deviation is 5° east.

   You observe the drift to be 12° left and the timed groundspeed is 152 kts.

   What wind is acting on the plane?

   ANS: ____________________

3. You are flying at an indicated altitude of 11,000 ft. where the temperature is 0° C. The indicated airspeed is 131 kts. The compass heading is 163°, the variation is 3° east and the deviation is 5° east.

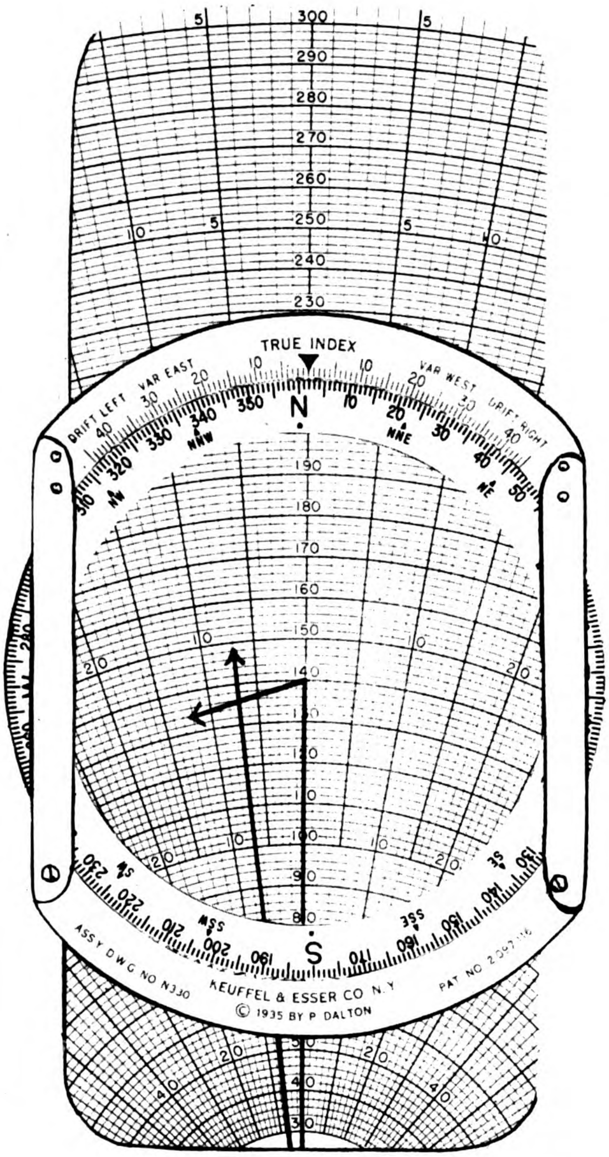
   The observed drift is 5° right and the timed groundspeed is 146 kts.

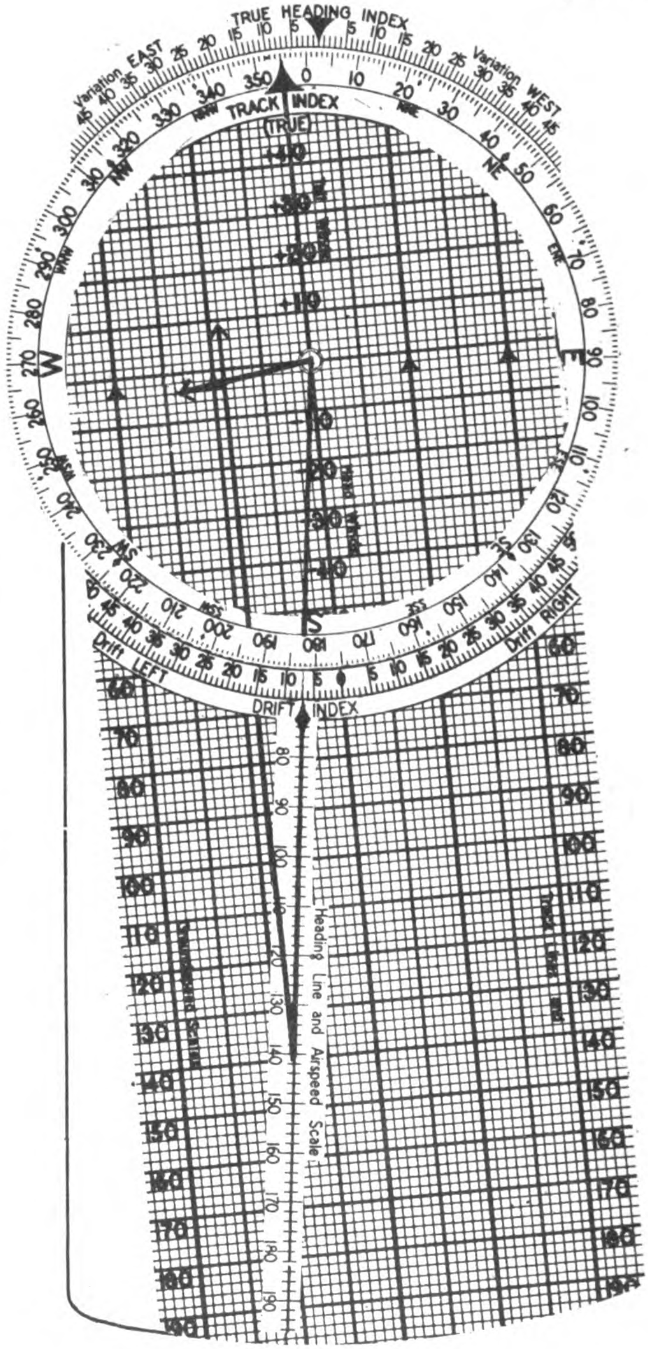
   What wind is acting on the plane?

   ANS: ____________________

(Given T.H. & T.A.S., Drift and Wind Direction - - Find Wind Velocity & Groundspeed)

CASE 4 CASE 4





The information given above may become available at low altitudes where the navigator assumes that the direction of the wind as seen on the surface is the same as that acting on the plane. Drift is obtained by drift indicator.

The following values are shown on the computers: Magnetic heading 352°, T.A.S. 140 MPH, Variation 10° east, Drift 7° left, Wind Direction 075° true.

Solution of the problem above shows the wind velocity to be 18 MPH and the groundspeed 136 MPH.

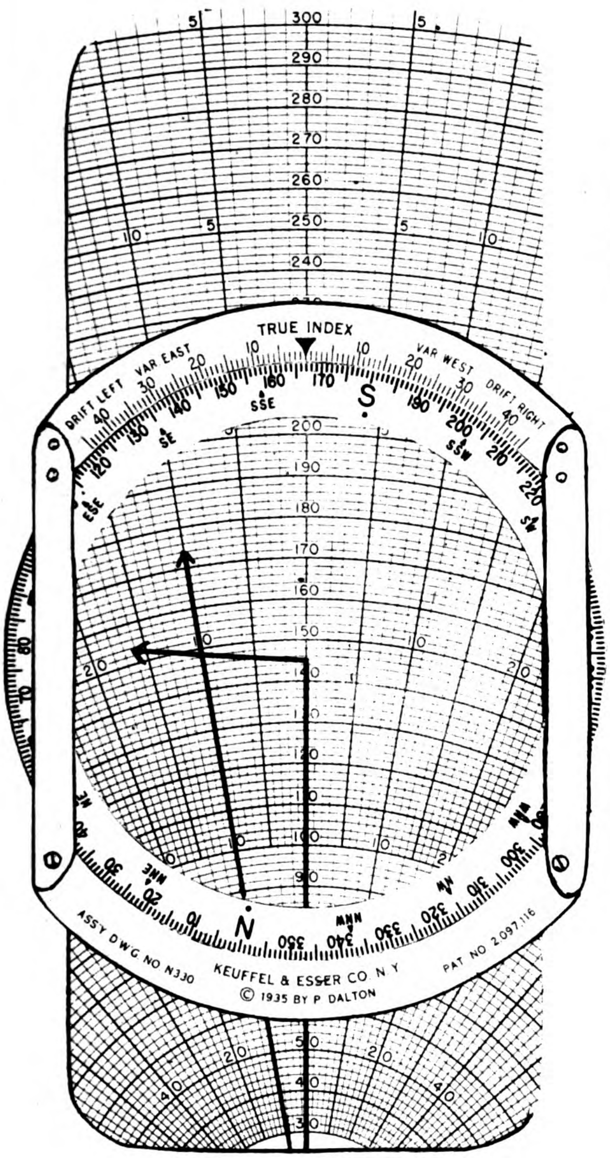
EXAMPLE PROBLEM

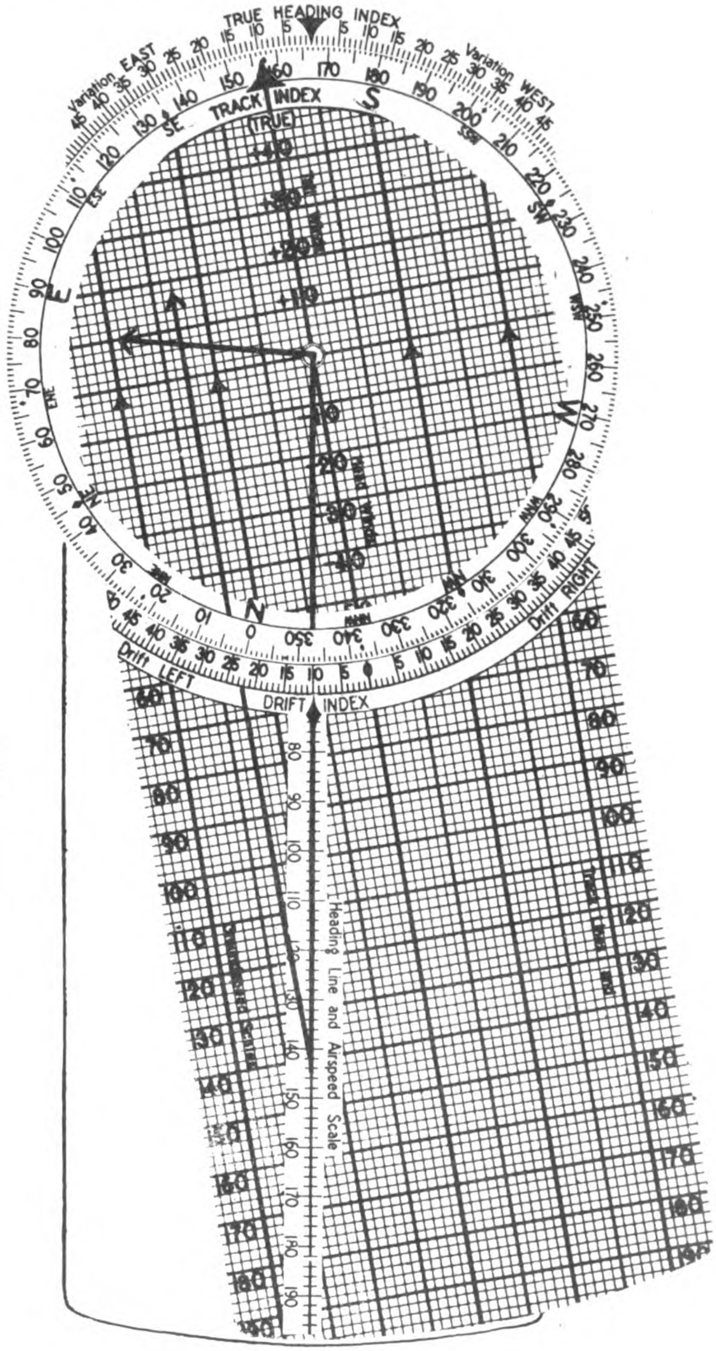
1. You are flying at 2,000 ft. on a magnetic heading of 175° (Var. 8° west). Your true airspeed is 145 MPH. You observe 10° left drift and note the wind direction to be 260° (true always).

   Illustrate this problem on both computers.

   What is the wind velocity? What is the groundspeed?

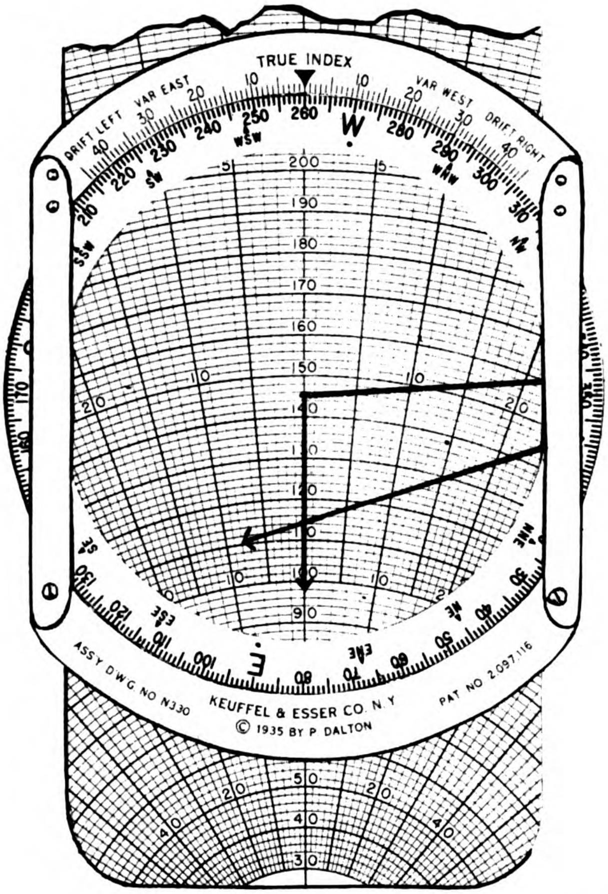
   ANS:

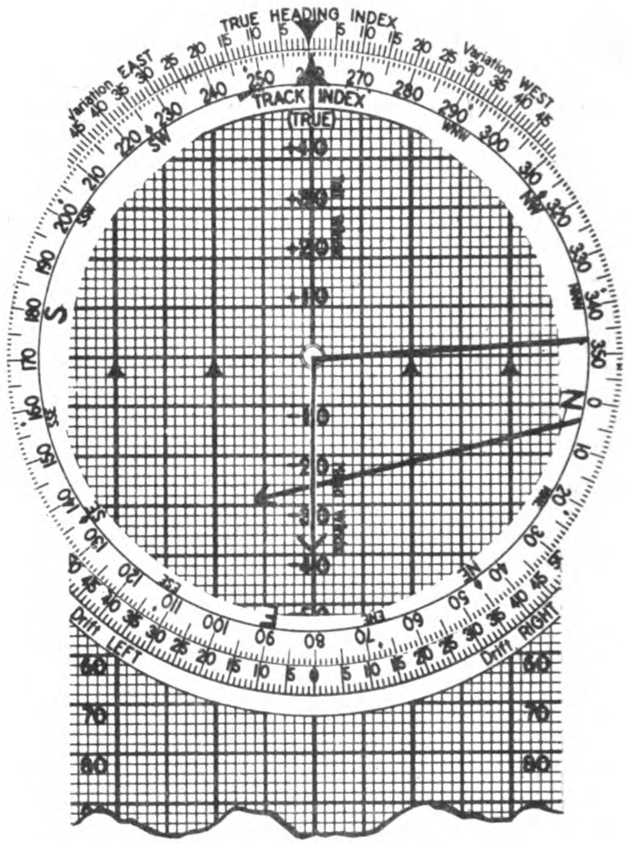




The problem is shown above, illustrated on both computers.

The groundspeed, measured along the track lines is 149 MPH.





The method of measuring the wind velocity is illustrated above. The velocity is 26 MPH. The direction was already established by observation.

CLASSROOM PROBLEMS

1. You are flying at an indicated altitude of 2,000 ft. where the temperature is 0° C. The indicated airspeed is 138 kts. The compass heading is 277°, the variation is 21° west and the deviation is 3° east.

   You observe 10° **right** drift and note that the surface wind direction is 180° (always true).

   Assuming the wind direction at 2,000 ft. to be the same as that at your flight altitude, what is the wind velocity and what is the groundspeed?

   ANS:____

2. Your compass heading is 035°, the compass error is 18° east, the true airspeed is 153 kts. You observe 5° right drift and the wind direction is 270°. What is the wind velocity and groundspeed?

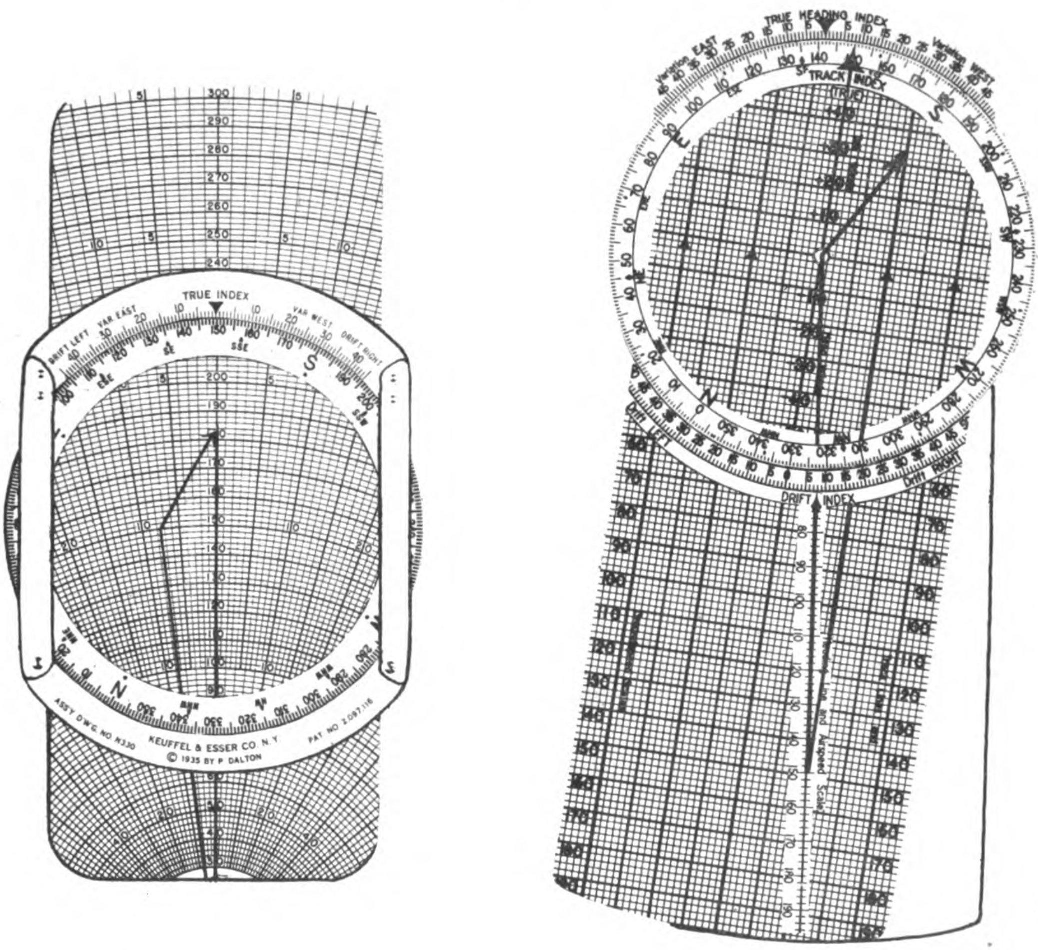
   ANS:____

3. Your magnetic heading is 155°, the variation is 11° east, your indicated altitude is 1600 ft. and the temperature is +20° C. Your indicated airspeed is 166 kts. You observe 3° left drift. The surface wind direction is 300°. What is the wind direction and groundspeed?

ANS:____

(Given Wind Direction and Velocity, T.A.S. & Desired Track - - find True Heading and Groundspeed)

CASE 5 CASE 5



With the "given" information at hand, the navigator determines the true heading necessary to maintain the desired track and also the groundspeed along the track. This is the problem the navigator solves in planning a flight. The same problem must be solved during flight after wind and position have been determined.

The following information is on both computers:

Wind	North	40 MPH
Desired Track		150°
Cruising Airspeed		150 MPH

Notice the manner in which the wind arrow is drawn on the Model J computer. On this computer, the line that was formerly used for true heading and airspeed is

now used for track and groundspeed. Inspection of the drift lines shows that the true heading will have to be 8° left of the track.

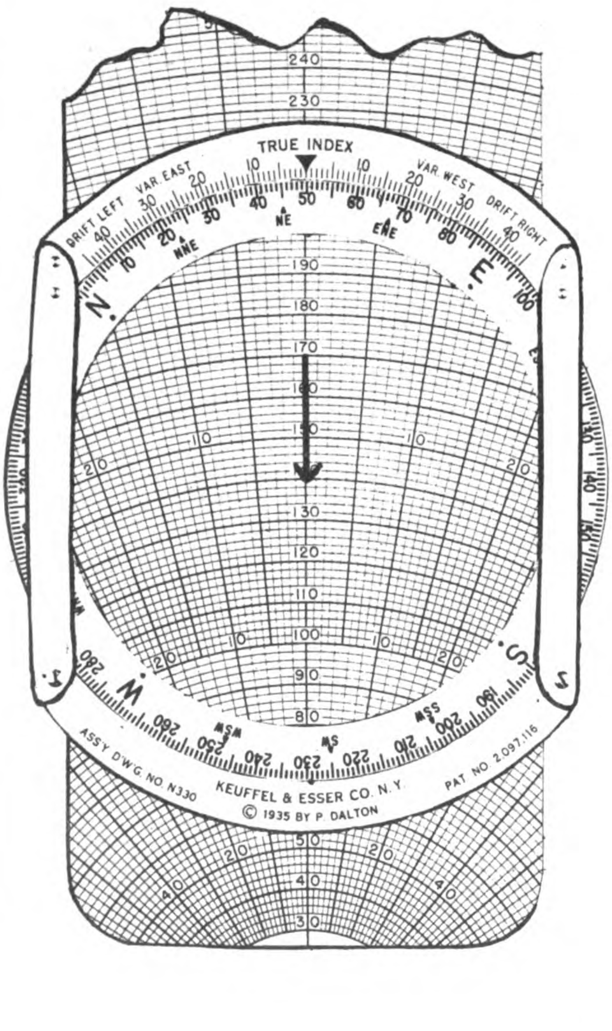
When using the Mark VII, set the desired track (150°) on the track index and keep it there while closing the triangle as shown. When the triangle is closed, the required true heading is read opposite the true heading index as heretofore.

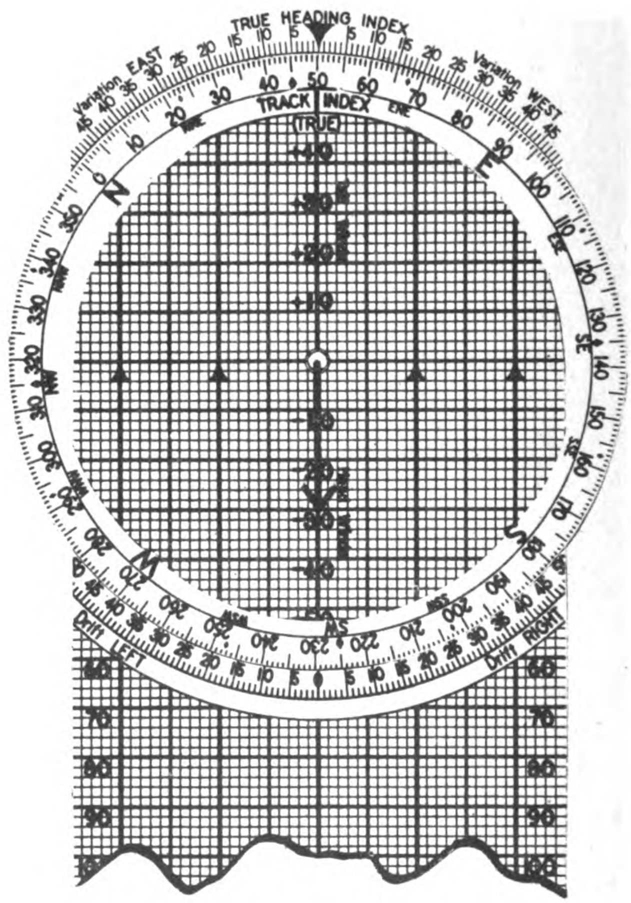
T.H. = 142°   G.S. = 183 MPH

EXAMPLE PROBLEM

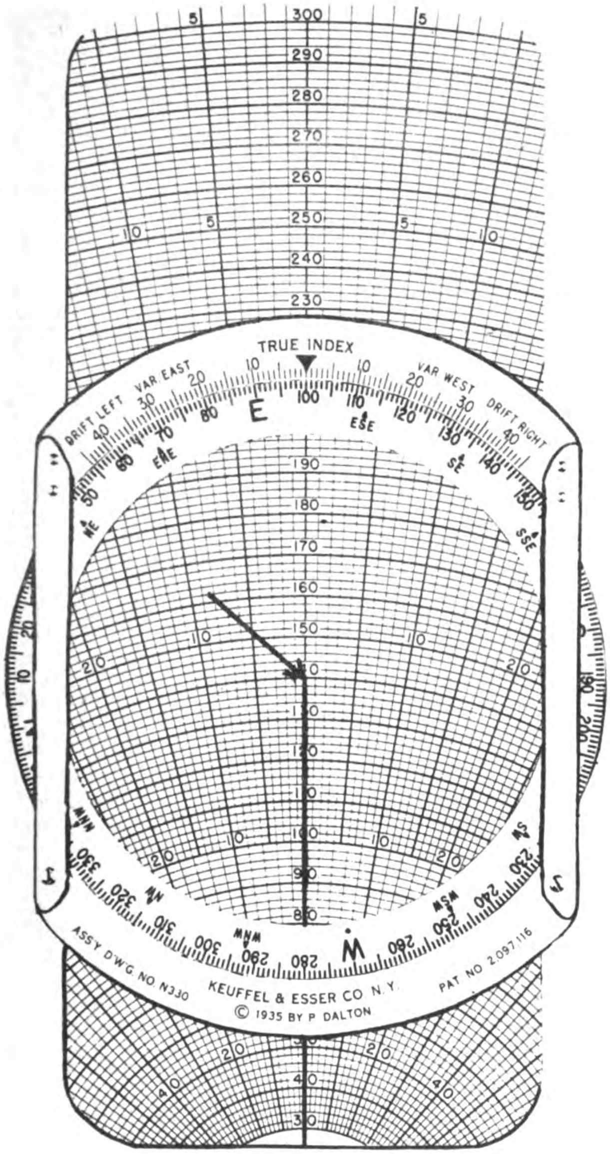
1. From the following information, determine the required true heading. Also determine groundspeed that will be made along the track

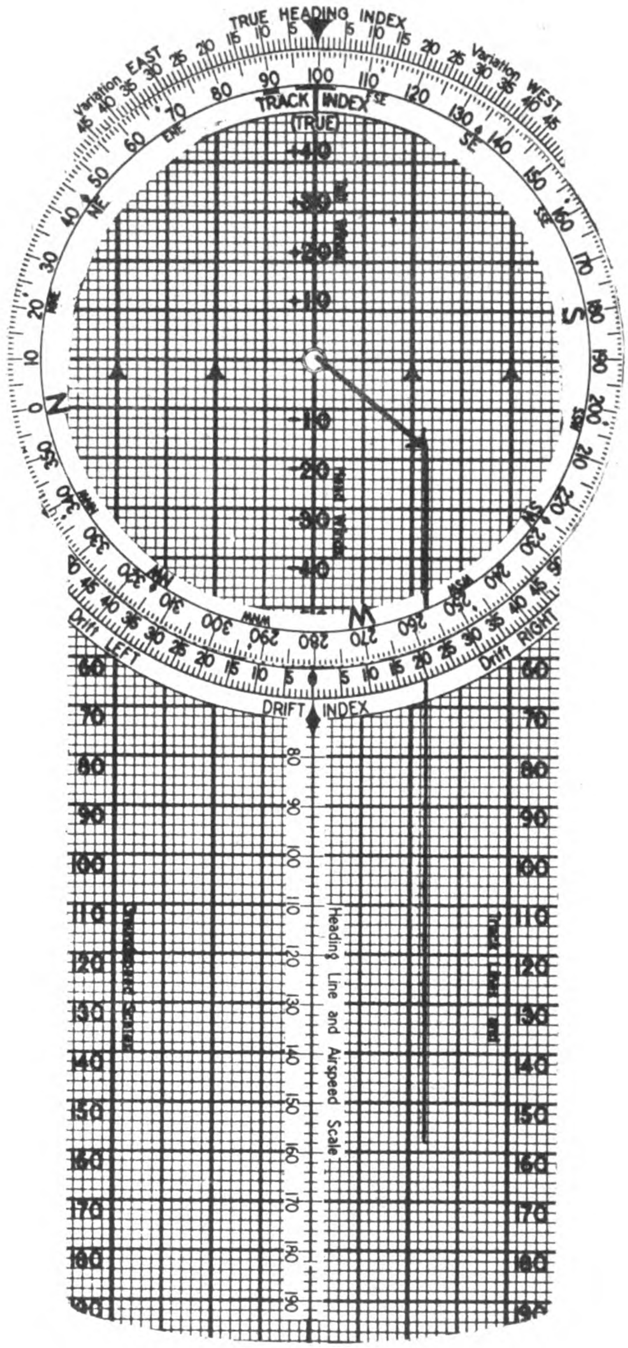
Wind	050°-30 kts.
Desired Track	100°
True Airspeed	140 kts.



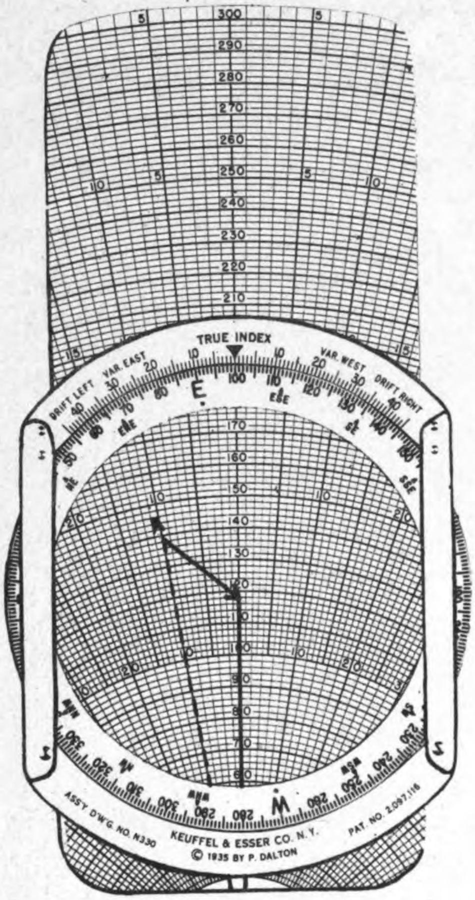


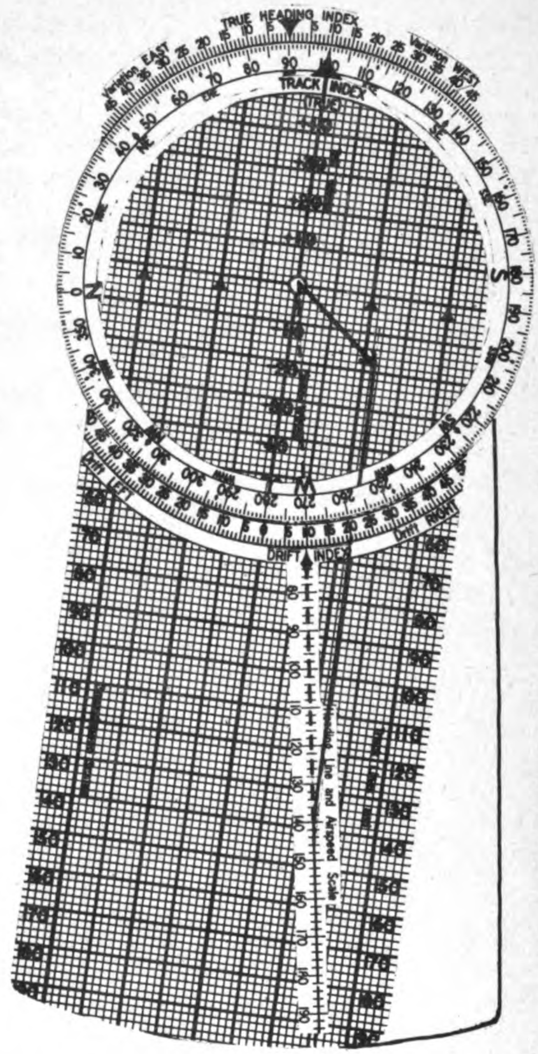
The diagrams above show the 050°-30 kt. wind drawn on each computer.





The diagrams above show the desired track (100°) set on each computer.





The completed triangle of velocities is shown in the diagrams above. When using the Model J computer at the left, the true heading is found by inspection at "A" to be 10° left of the track. If the Mark VII computer is used, the true heading appears underneath the true heading index.

The groundspeed is always the length of the track line.

ANS: True heading to maintain: 90°. Groundspeed on desired track: 118 kts.

CLASSROOM PROBLEMS

1. The track desired is 160°. The wind is 040°-20 kts. The best cruising airspeed is 125 kts. What will the true heading and groundspeed be?

   ANS: ______________________________

2. The track desired is 242°. The wind is 090°-40 kts. The best cruising airspeed is 150 kts. What will the true heading and groundspeed be?

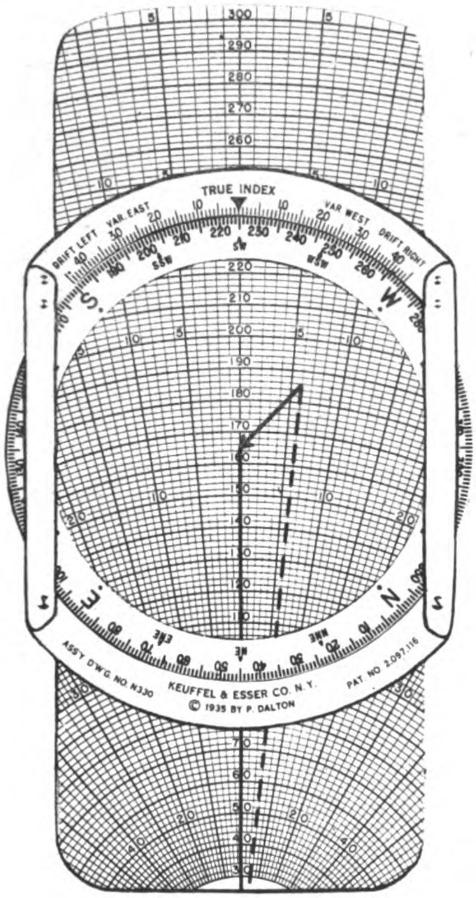
   ANS: ______________________________

3. The track desired is 321°. The wind is 165°-27 MPH. The best cruising airspeed is 183 MPH. What will the true heading and groundspeed be?

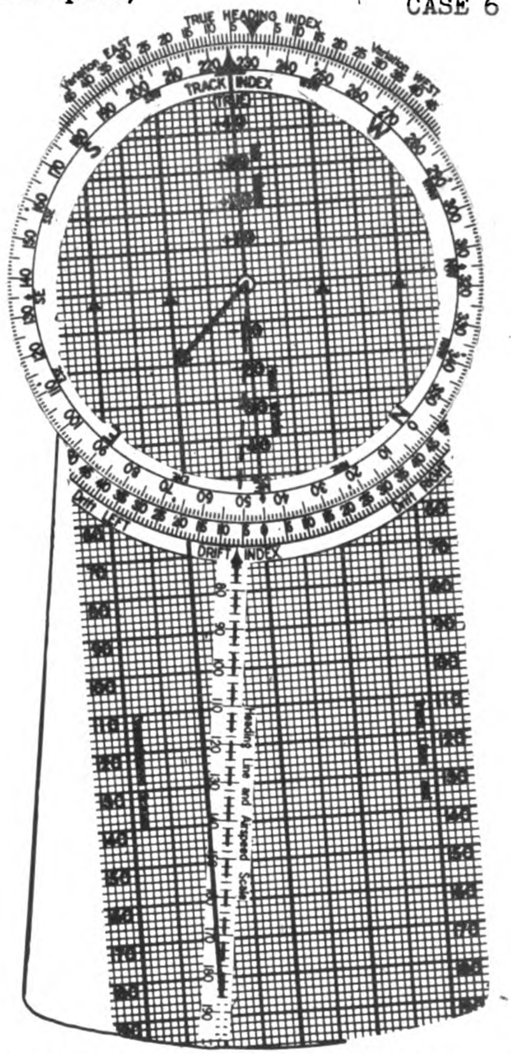
ANS: ____________________

(Given Wind Direction and Velocity, Track Desired and Groundspeed Desired - - Find True Heading and True Airspeed)

CASE 6



CASE 6



With the "given" information at hand the navigator determines the true heading and airspeed necessary to maintain the desired track and achieve the desired groundspeed. This is the problem solved by the navigator in planning and executing flights according to a time schedule.

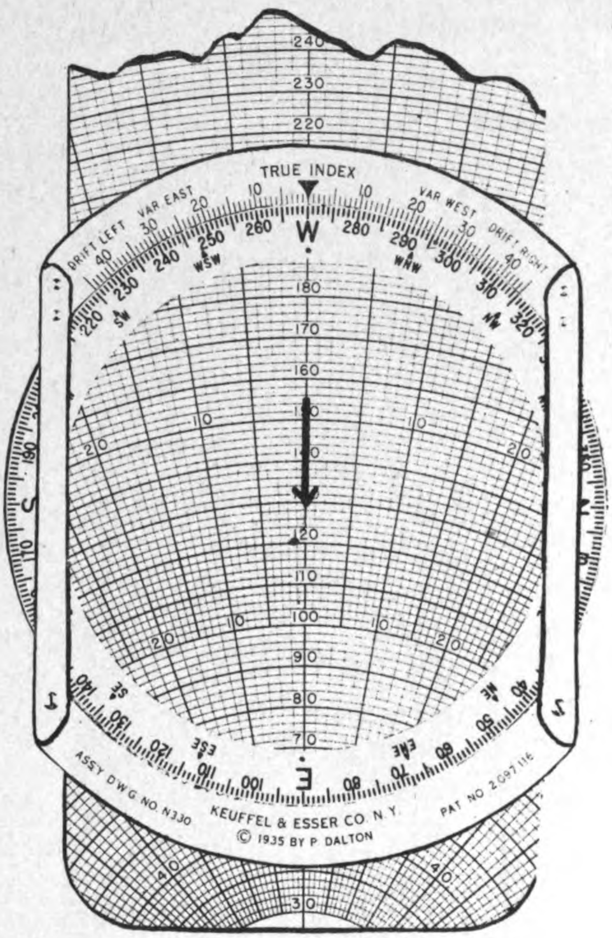
Wind	West 28 MPH
Track desired	225°
G.S. desired	165 MPH

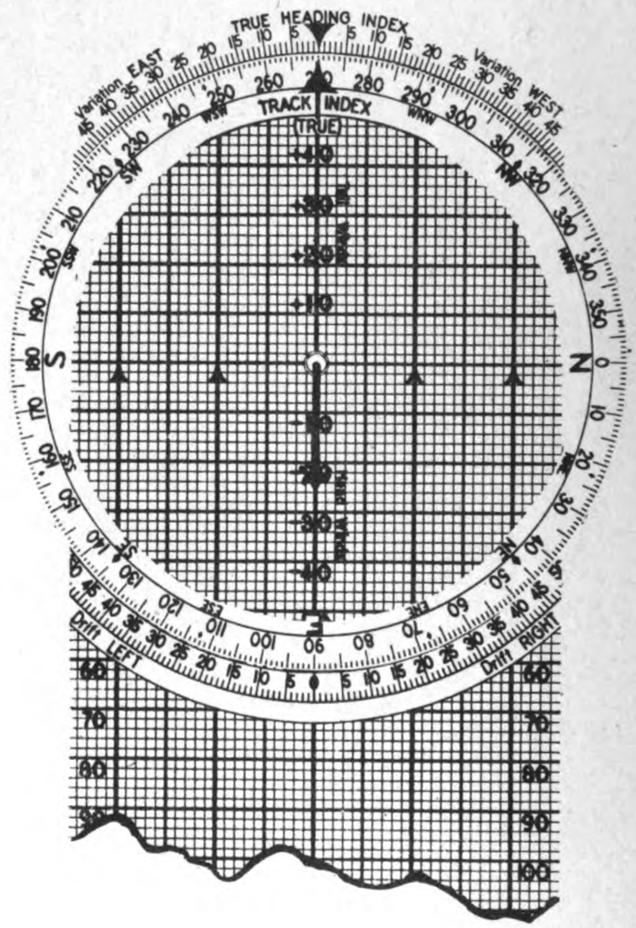
The proceedure is the same as that followed in the last type of problem with this exception: After the track line has been drawn, its length is at once made equal to the groundspeed.

For this condition of wind, track and groundspeed, the required true heading is 231° and the airspeed is 186 MPH.

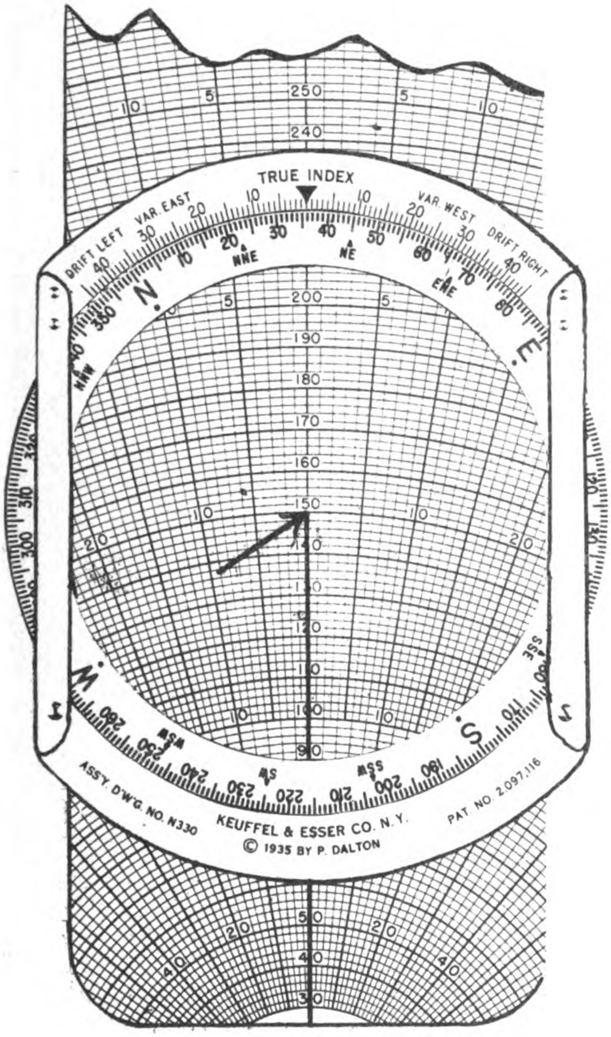
EXAMPLE PROBLEM

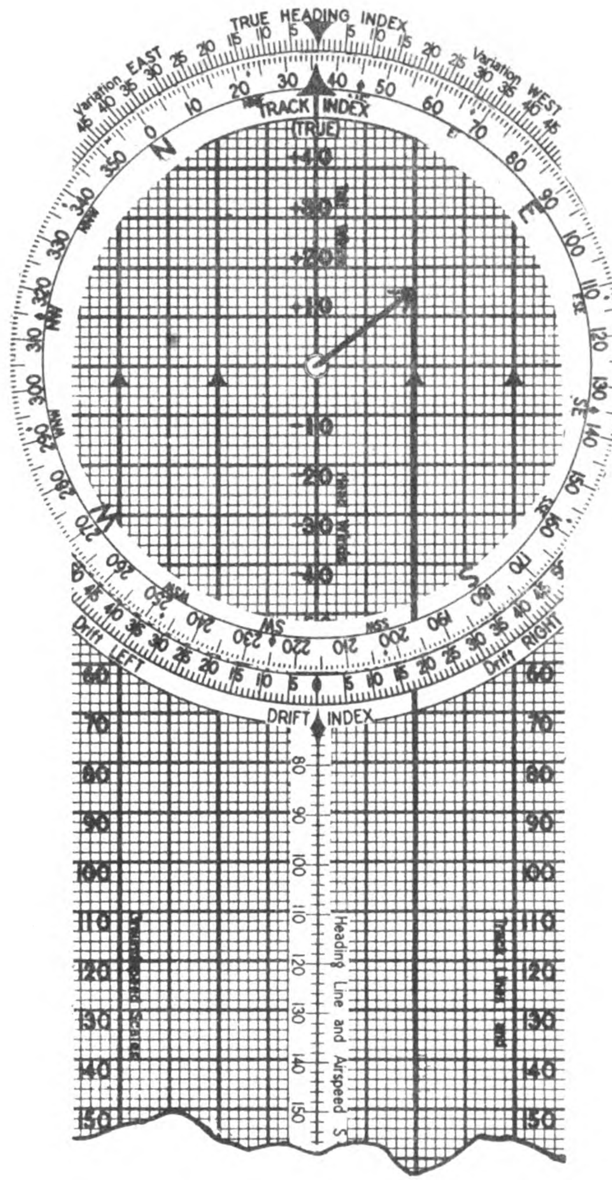
1. A scheduled flight calls for making 150 MPH on track 036°. The wind is 270° -25 MPH. What true heading and airspeed must be maintained? Show this problem on both computers.



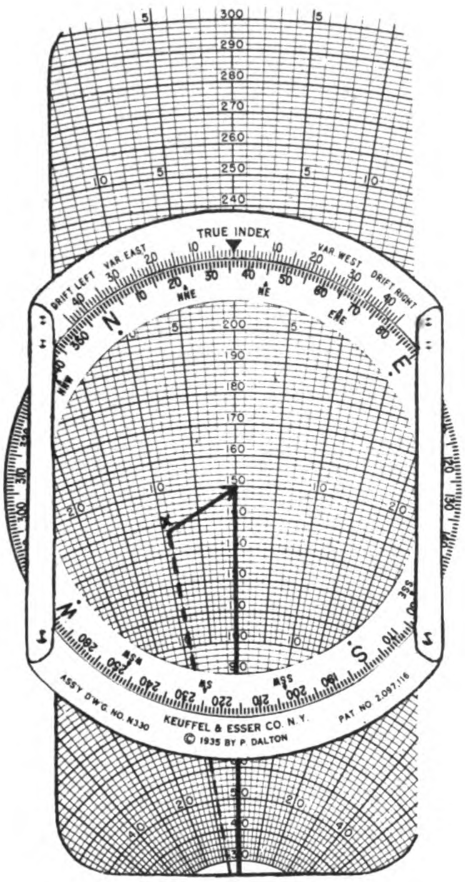


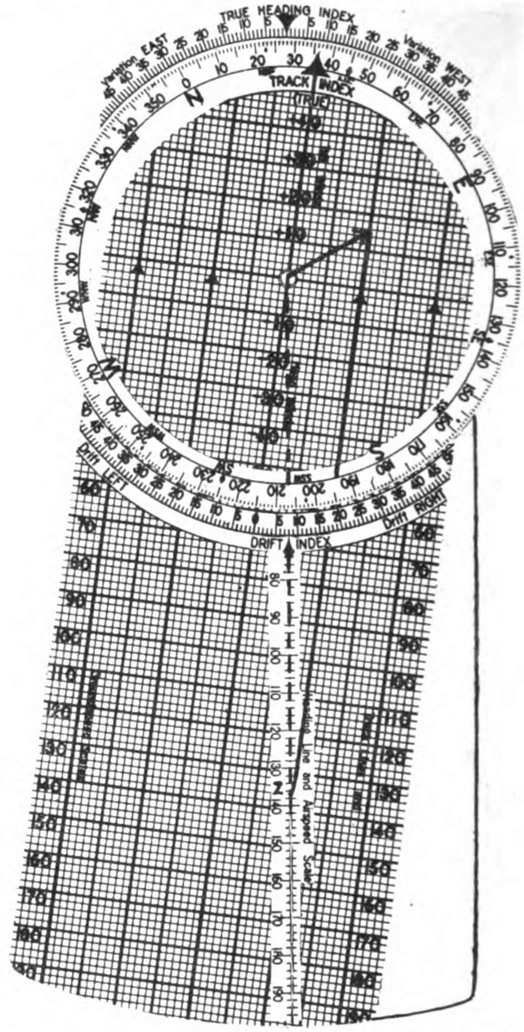
In the left diagram above the wind is shown drawn on the Model J computer. In the right diagram above the wind is shown drawn on the Mark VII.





In the diagram above, the track and <u>groundspeed</u> are shown drawn on each computer.





The completed triangle of velocities is shown above on both computers. When using the Model J, the true heading is found by inspection to be $8\frac{1}{2}^{\circ}$ left of the track and the required airspeed is shown at "x".

When using the Mark VII, the true heading is found opposite the true heading index, and the airspeed is read at "Z" on the airspeed scale.

The true heading is 028°. The required airspeed is 137 MPH.

CLASSROOM PROBLEMS

1. You are required to make a track of 055° and a groundspeed of 135 MPH. The wind is 000°-36 MPH. What true heading and airspeed must be maintained?

   ANS:______________________________

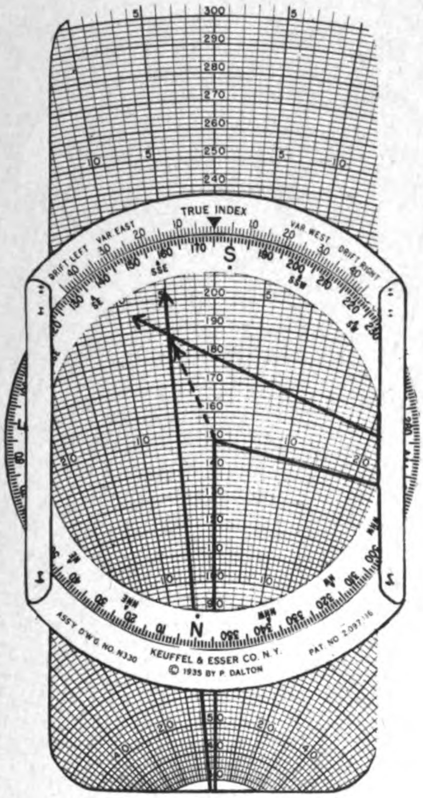
2. You are required to make a track of 198° and a groundspeed of 145 MPH. The wind is 270°-15 MPH. What true heading and airspeed must be maintained?

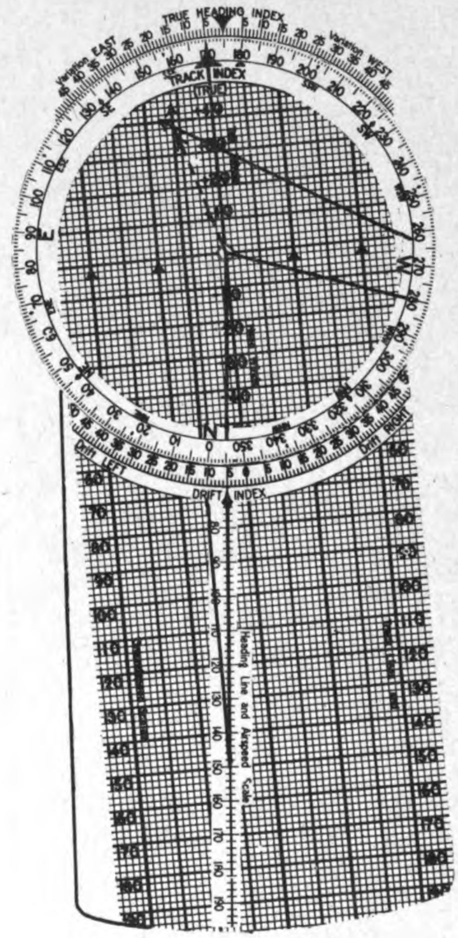
   ANS:______________________________

3. You must make a 400 mile flight in 2-1/2 hours. The track is 140° and the wind is 330°-18 MPH. What true heading and airspeed must be maintained?

ANS:____

SOLVING DOUBLE DRIFT PROBLEM WITH COMPUTER





Either the Model J or Mark VII computer can be used to speed up the graphic solution of the double drift problem. A typical problem requiring the determination of wind from the results of two drift observations is shown above.

The following information has been drawn graphically on each computer:

T.H. 100°	T.A.S. 150 MPH.	10° right drift
T.H. 175°	Same airspeed	5° left drift.

The wind that causes both these drifts is shown as a dotted line. The direction and velocity can be found by rotating the circular disk until the wind arrow points vertically downward. The direction is that shown opposite the true index. The velocity can be measured on any convenient portion of the airspeed scale.

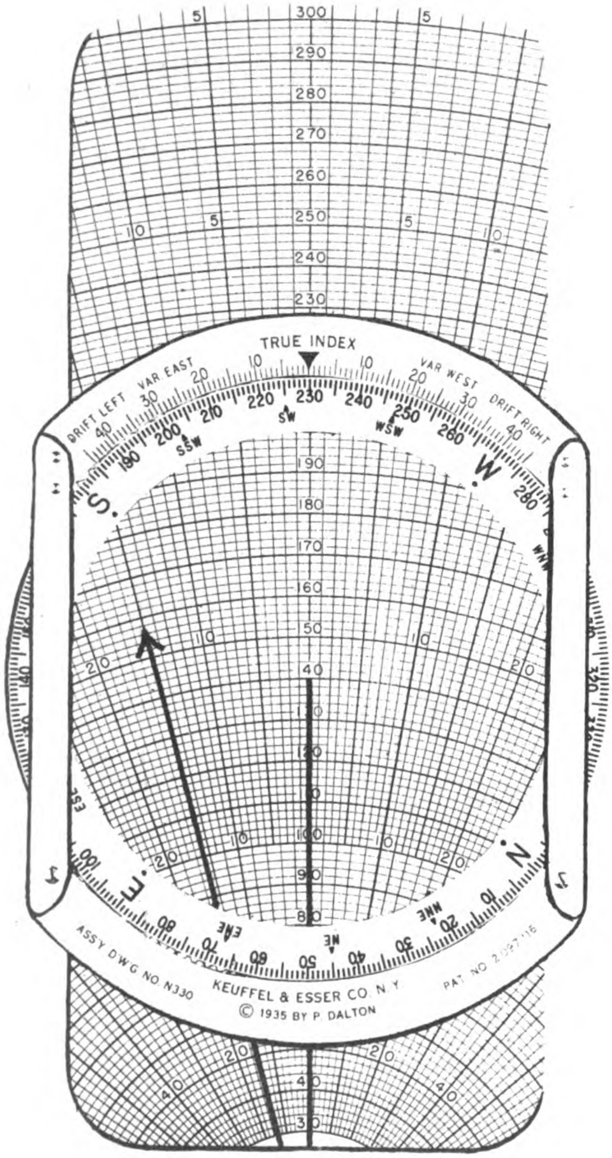
In the problem above the wind is 330°-40 MPH.

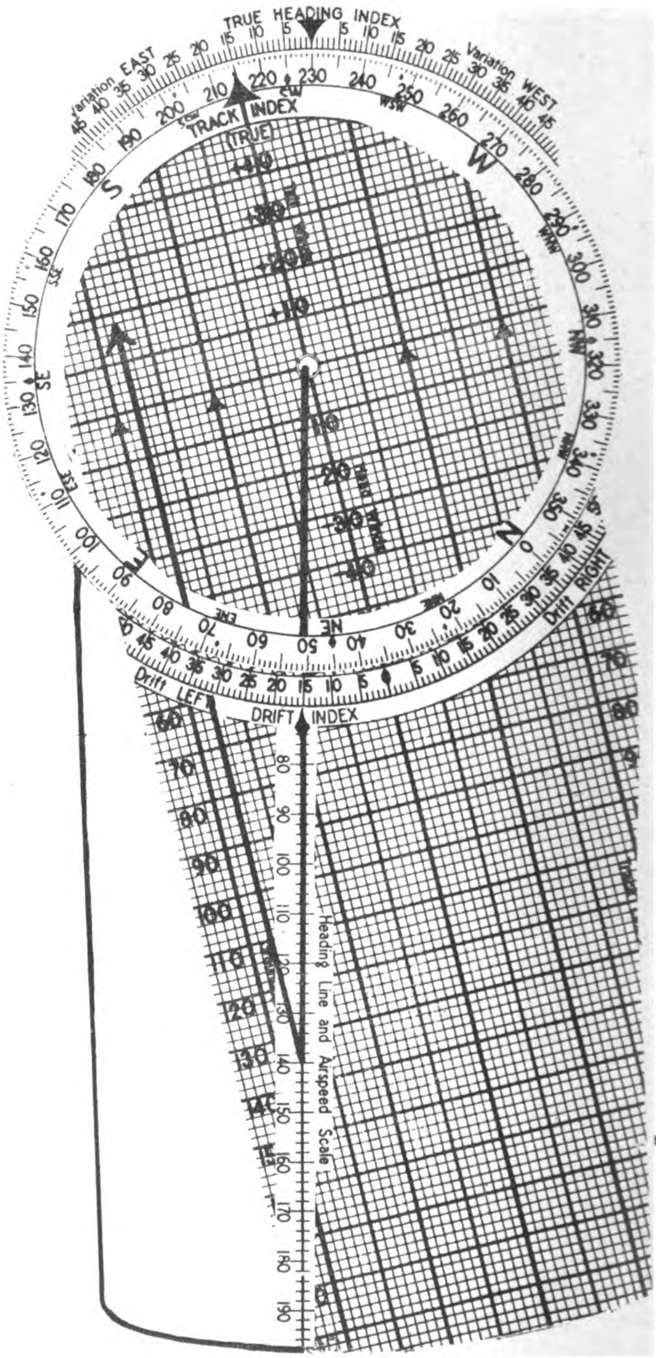
EXAMPLE PROBLEM

1. You observe 15° left drift while maintaining a true heading of 230° and a true airspeed of 140 kts.

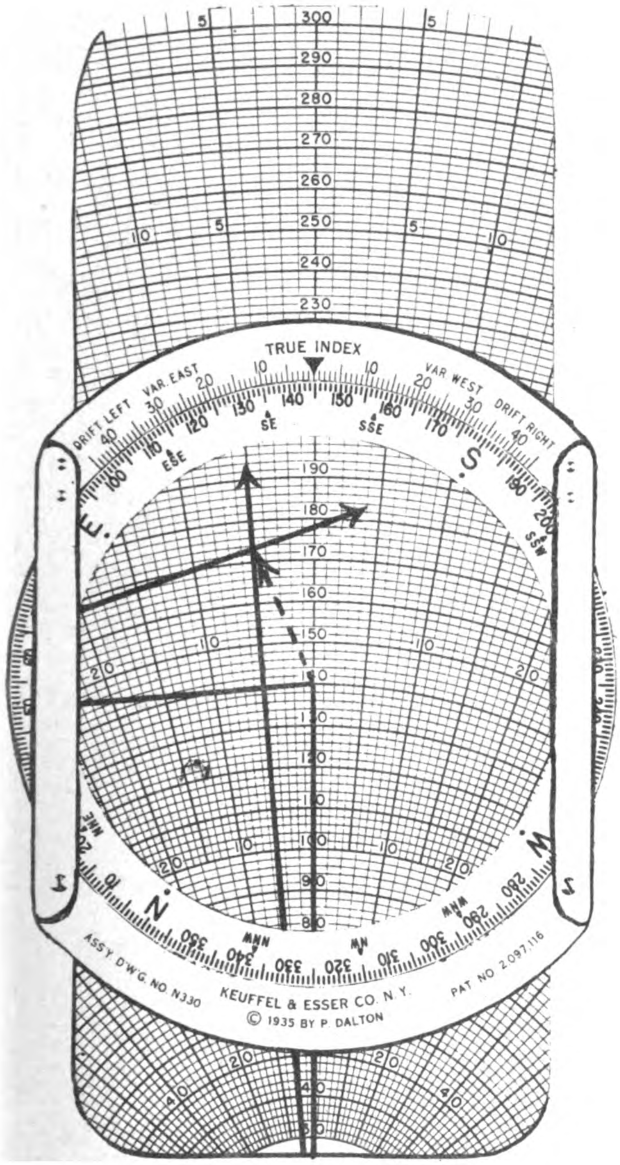
   You alter the true heading to 145° (same airspeed) and observe 5° left drift.

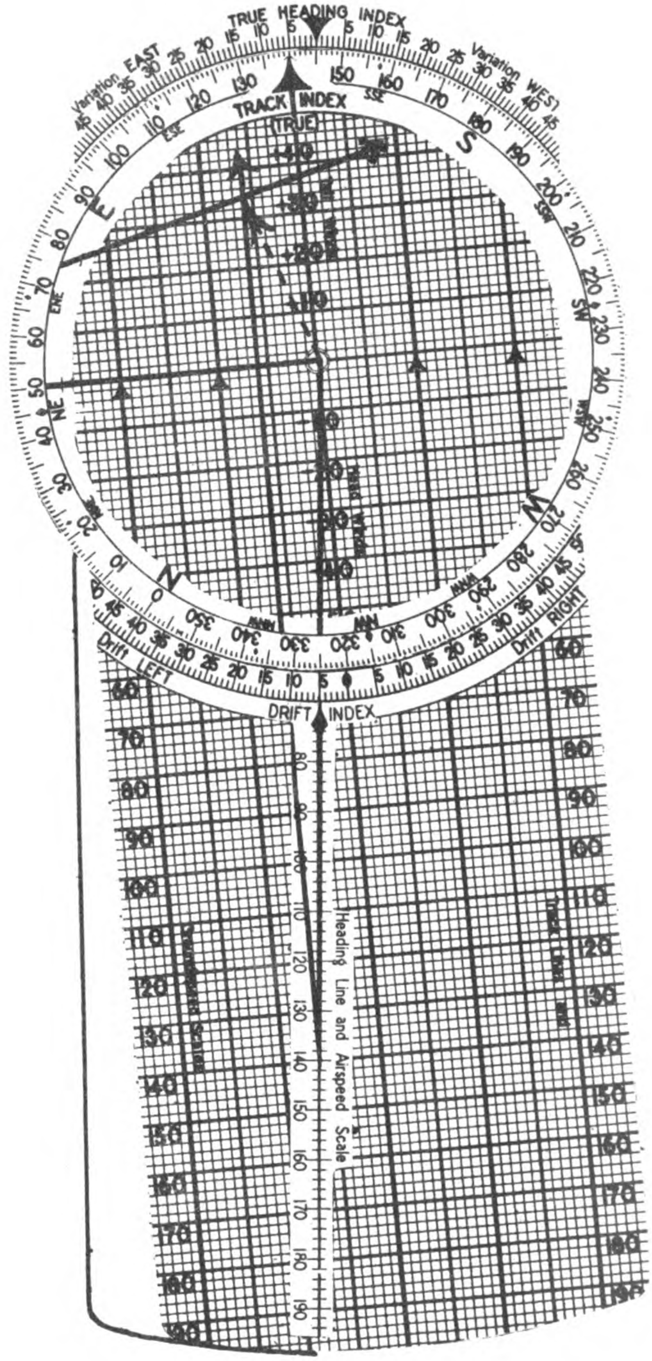
   What wind is acting on the plane? Show the problem graphically on both the Model J and Mark VII computers.



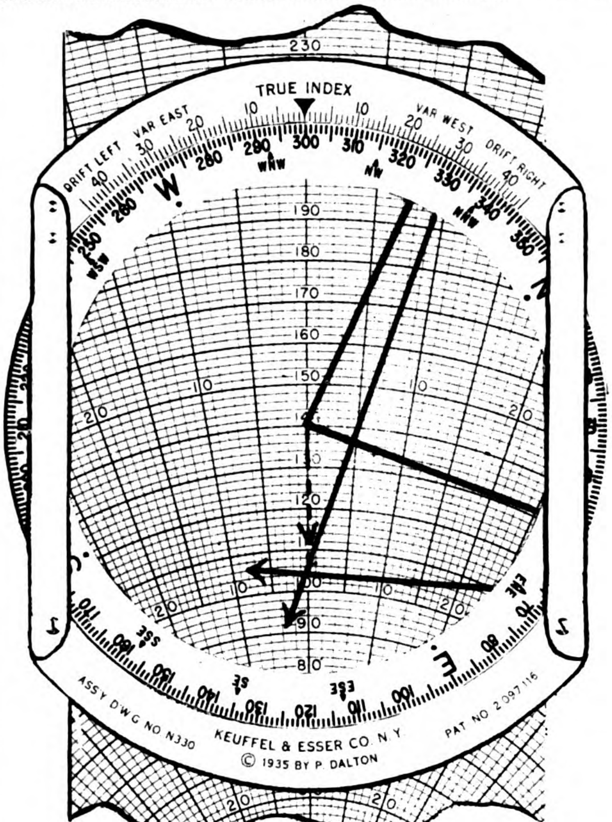


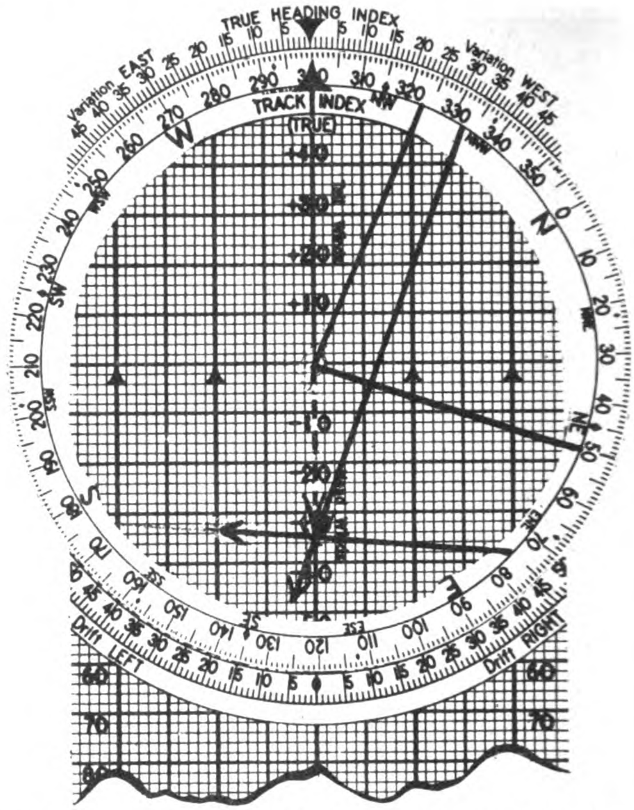
In the illustrations above, a true heading of 230°, a true airspeed of 140 kts. and a track of 215° are shown on each computer.





In the illustrations above, the second true heading and resulting track are also shown. The wind is shown as a dotted line.





In the diagrams above the wind arrow has been rotated until it points vertically downward. The wind is 300°-36 kts.

CLASSROOM PROBLEMS

1. You are heading 085° magnetic where the variation is 15° east; the true airspeed is 156 kts; the observed drift is 6° left.

   The magnetic heading is changed to 170°, and the drift becomes 4° right. What wind is acting on the plane?

   ANS: ______________________________

2. You are flying at an indicated altitude of 6500 ft. where the temperature is +10° C. The indicated airspeed is 133 kts. On heading 333° true, you observe 11° right drift, and on heading 042° true the drift is 0°. What wind is acting on the plane?

   ANS: ______________________________

3. You are flying at an indicated altitude of 2300 ft. where the temperature is -5° C. The indicated airspeed is 141 kts. On heading 269° by compass (Var. 18° west, Dev. 3° east) you observe 17° left drift.

   On heading 350° by compass (Dev. 1° east) you observe 8° left drift. What wind is acting on your plane?

   ANS: ______________________________

4. Your true airspeed is 130 MPH. On true heading 100°, you observe 10° left drift.

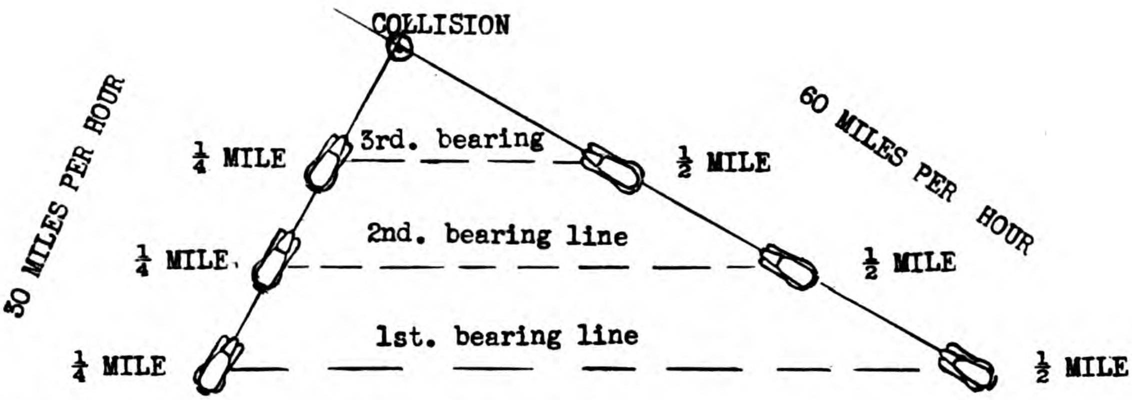
You alter heading to 145° true and observe 12° left drift.

You alter heading to 055° true and observe 1° left drift.

What wind is acting on the plane? What true heading and airspeed will have to be maintained to make track 080° and groundspeed 170 MPH?

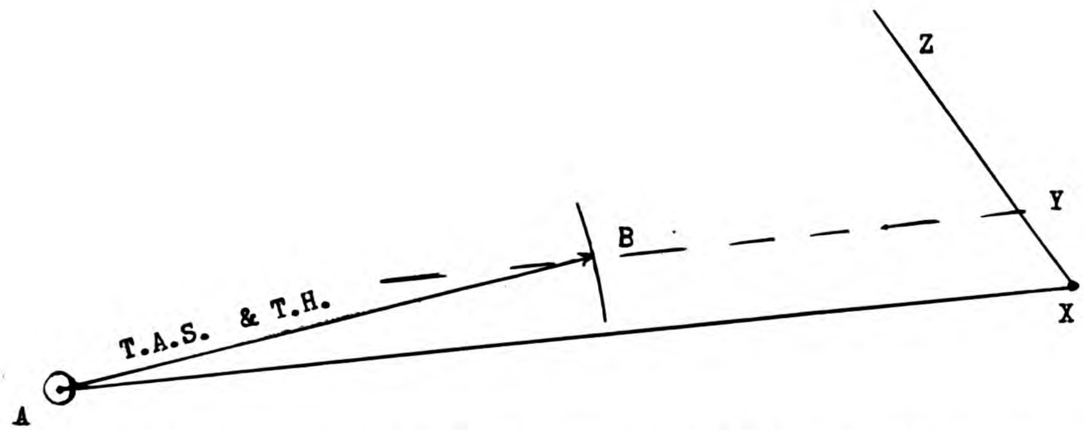
ANS:____

SIMPLE INTERCEPTION



In the diagram above, two automobiles are shown approaching a highway intersection where they will collide. They are traveling toward each other in such a manner that <u>the line of bearing between them does not change</u>.

<u>Whenever</u> two moving objects travel toward each other in such a manner that the line of bearing between them does not change they will meet (intercept).

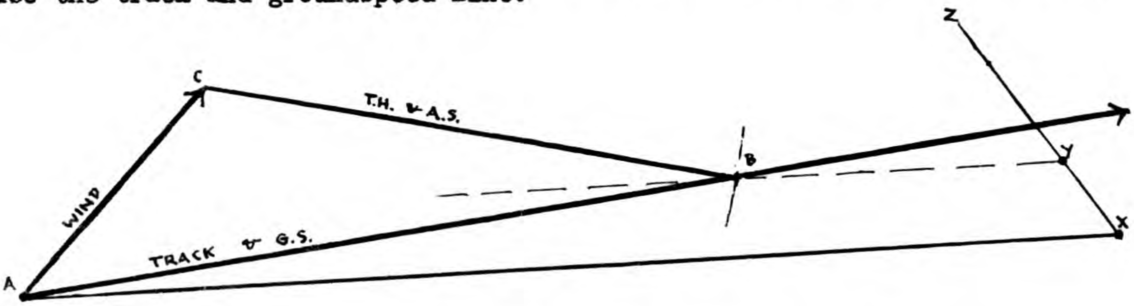


In the diagram above you are at "A" and a ship is at "X". The ship is steaming toward "Z" and will be at "Y" at the end of one hour.

Head your plane in such a manner that when the ship is at "Y", you will both be joined by the same bearing line that joined you at "A" and "X".

The true heading is obtained by swinging an arc equal to your airspeed from point "A" so as to cross the 2nd bearing line as at "B".

This line A-B is the true heading and airspeed line. If there is no wind, it is also the track and groundspeed line.



In the diagram above the same situation exists except for the addition of a strong wind. The plane must be headed in such a manner that both plane and ship are joined by the 2nd bearing line at the end of an hour. To obtain the necessary true heading, swing the airspeed arc from the end of the wind arrow to cross the 2nd bearing.

EXAMPLE PROBLEMS

1. Will two planes collide if the line of bearing between them remains constant?

   ANS: Yes. Pilots avoid collision by altering the heading so as to make the bearing change. So do ship's officers.

2. In the second diagram above, using a scale of 40 miles per inch, determine the distance between the plane and the ship at the start.

   ANS: 240 miles.

3. How much closer together were they at the end of one hour?

   ANS: 170 miles. This hourly rate of approach is called the rate of interception.

4. Is the rate of interception always reckoned along the line of constant bearing?

   ANS: Always.

5. Could the rate of interception ever be measured along the track line?

   ANS: Not unless the line of bearing and track line were one and the same.

6. Is the rate of interception ever the same as the groundspeed?

   ANS: Yes, when approaching a stationary vessel or an airport.

CLASSROOM PROBLEMS

1. In the example problem just given, determine the time required to achieve interception. Use a scale of 40 miles per inch.

   ANS: ______________________________

2. What track will the plane follow?

   ANS: ______________________________

3. How far will the ship travel before it is intercepted?

   ANS: ______________________________

4. Will this interception occur at the intersection of the tracks of the plane and ship?

   ANS: ______________________________

5. What groundspeed is the plane making in this problem?

   ANS: ______________________________

6. Solve the following problem graphically:

   A ship is located 240 miles west of your plane. It is steaming true north at the rate of 20 MPH. Your true airspeed is 180 MPH. There is no wind.

   What true heading must you maintain to intercept the ship? What is the rate of interception? How long will it take to intercept the ship?

7. Solve the following problem graphically:

A ship is located 260 nautical miles 120° from your plane. It is steaming on track 240° at a rate of 30 kts. Your true airspeed is 120 kts. The wind is 180°-30 kts.

What true heading must you maintain to intercept the ship? What is the rate of interception? How long will it take to intercept the ship? What track and groundspeed will you make?

8. Solve the following problem graphically:

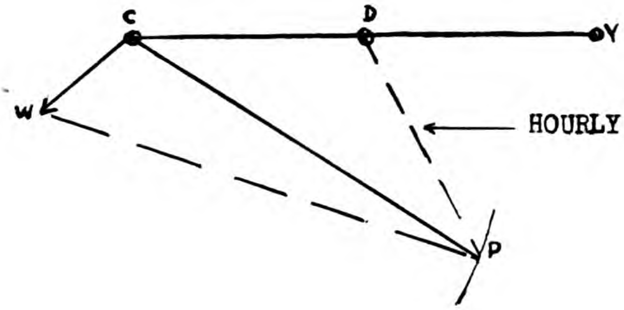
A ship is located 290 nautical miles 200° from your plane. It is steaming on track 270° at the rate of 30 kts.

You are flying at an indicated altitude of 8,000 ft. where the temperature is -10° C. The indicated airspeed is 149 kts. The wind is 300°-20 kts. What true heading must be maintained to intercept the ship? What compass heading must be maintained? (Allow 22° west error) What track and groundspeed will you make? What will the rate of interception be? How long will it take to intercept the ship?

ANS:

NOTE: The interception problem can be done on either the Model J or Mark VII computers. Since the bearing and distance of the ship from the plane must first be obtained from the chart, it is recommended that the problem itself be solved graphically on the chart.

RATE OF DEPARTURE FROM A MOVING BASE



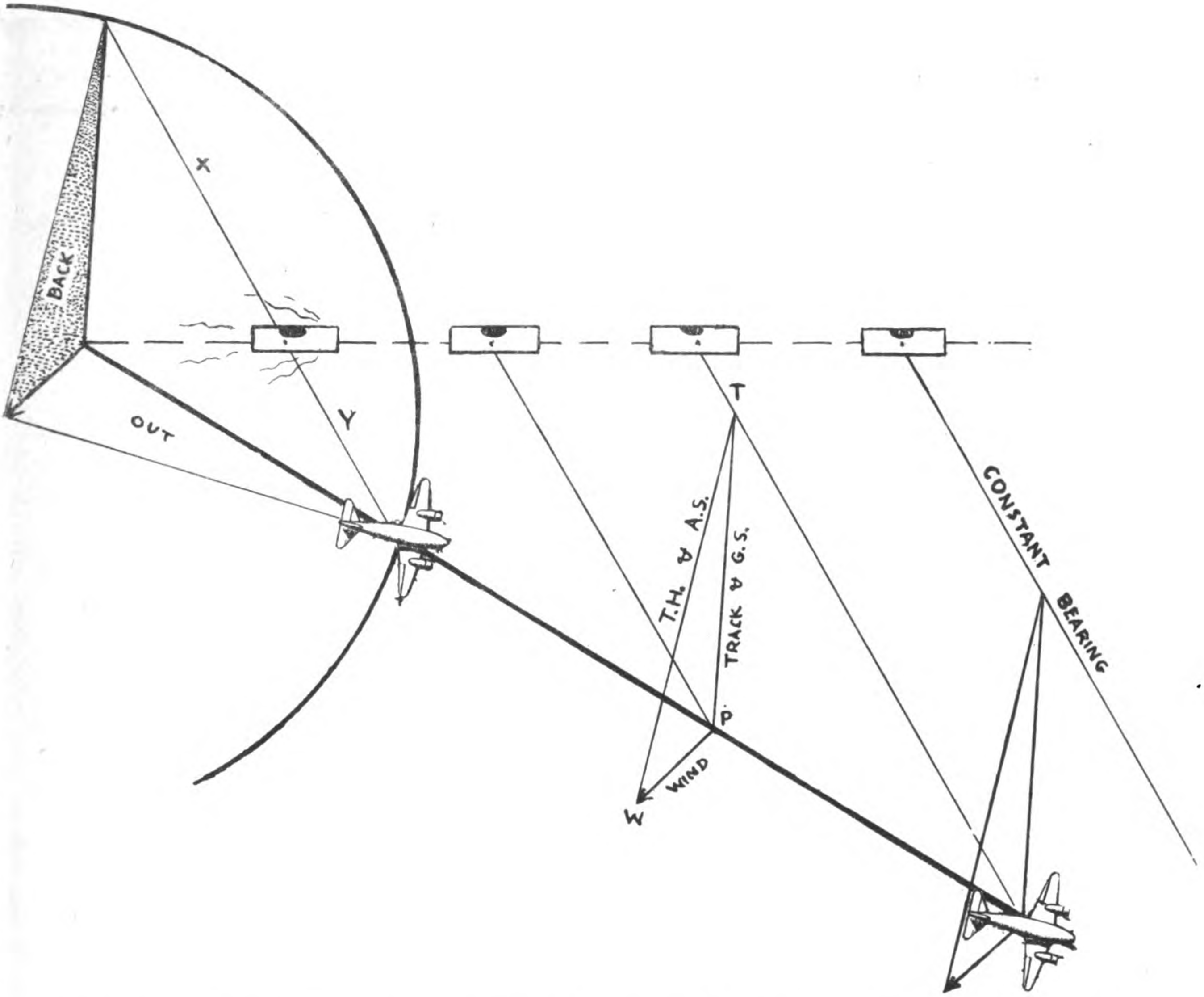
In the diagram above, a plane took off from a moving carrier at "C". The plane flew out along track C-P and arrived at "P" at the end of one hour. The carrier proceeded along track C-Y and arrived at "D" at the end of one hour.

The line joining the plane and carrier at the end of one hour (P-D) represents the rate of departure from the carrier.

If the plane and carrier continued along their tracks for another hour, the line joining them would be twice as long as it is now.

This line joining plane and carrier is the <u>line of constant bearing</u> (P-D) between them. If the plane turns back to the carrier, it must maintain a true heading that will at all times keep this bearing line constant; otherwise interception will not take place.

RATE OF RETURN TO A MOVING BASE



In the diagram above, the plane is shown at various positions along its track. Notice that the bearing line between the plane and carrier remains constant.

At the end of the 2nd and 3rd hours the navigator constructed the simple interception triangle of velocities.

These triangles are the same because the problem is the same. The problem in either case is to return without changing the constant bearing line.

<u>If the following discussion is not perfectly clear, review the simple interception problem</u>.

The distance separating the plane and carrier at any time is the distance that must be cut down when the plane turns to intercept the ship. Assume that the plane turns back to intercept the carrier at "P".

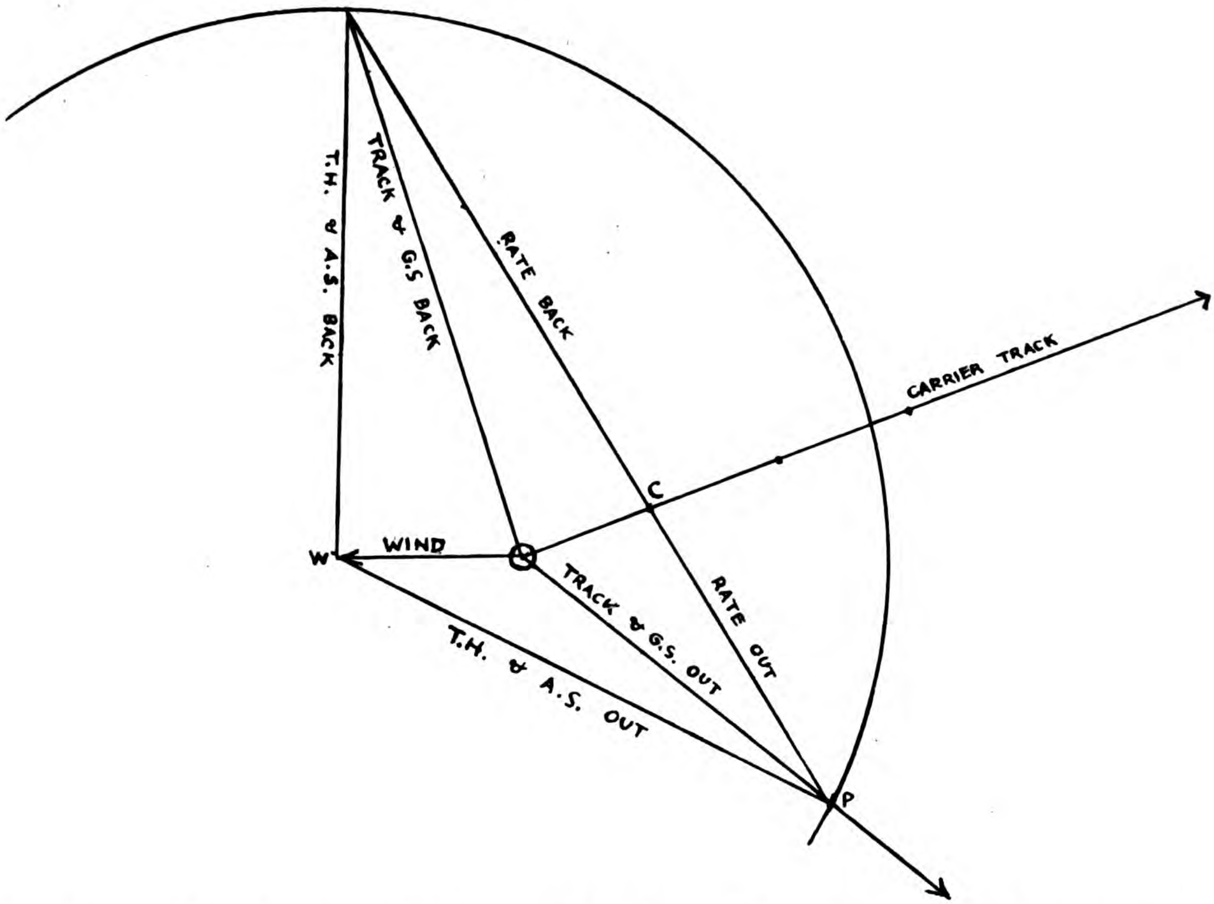
One hour after turning back, the plane is at "T". To find the rate of interception the remaining distance to the carrier must be subtracted from the distance that separated them when the plane turned.

Compare this rate of interception with the line "X" in the upper left portion of the diagram. The line "X" is equal to the rate of return to the carrier.

In the previous diagram, the line "Y" was shown to be the rate at which the plane left the carrier.

Instead of drawing an interception triangle at some point out on the track, the whole problem is usually drawn as shown at the upper left. In this manner tracks, groundspeeds, headings, and rates, both out and back, become known in advance.

RADIUS OF ACTION FROM A MOVING BASE



The diagram above is a graphical analysis of a radius of action problem in which the rate of departure and rate back to a moving carrier is determined. The rate out is 75 kts. and the rate back is 127 kts. in the problem above.

This information, together with the total allowable flight time, is used in one of the formulas previously proved to find how long the plane can fly out along its track before turning back to the carrier.

$$t_1 = \frac{Tr_1}{r_1 + r_2}$$

If, in the above problem, the plane can safely remain in the air for 5 hours, the time out to the turning point is found as follows:

$$\text{time} = \frac{5 \times 127}{75 + 127} \text{ or } 3.14 \text{ hours}$$

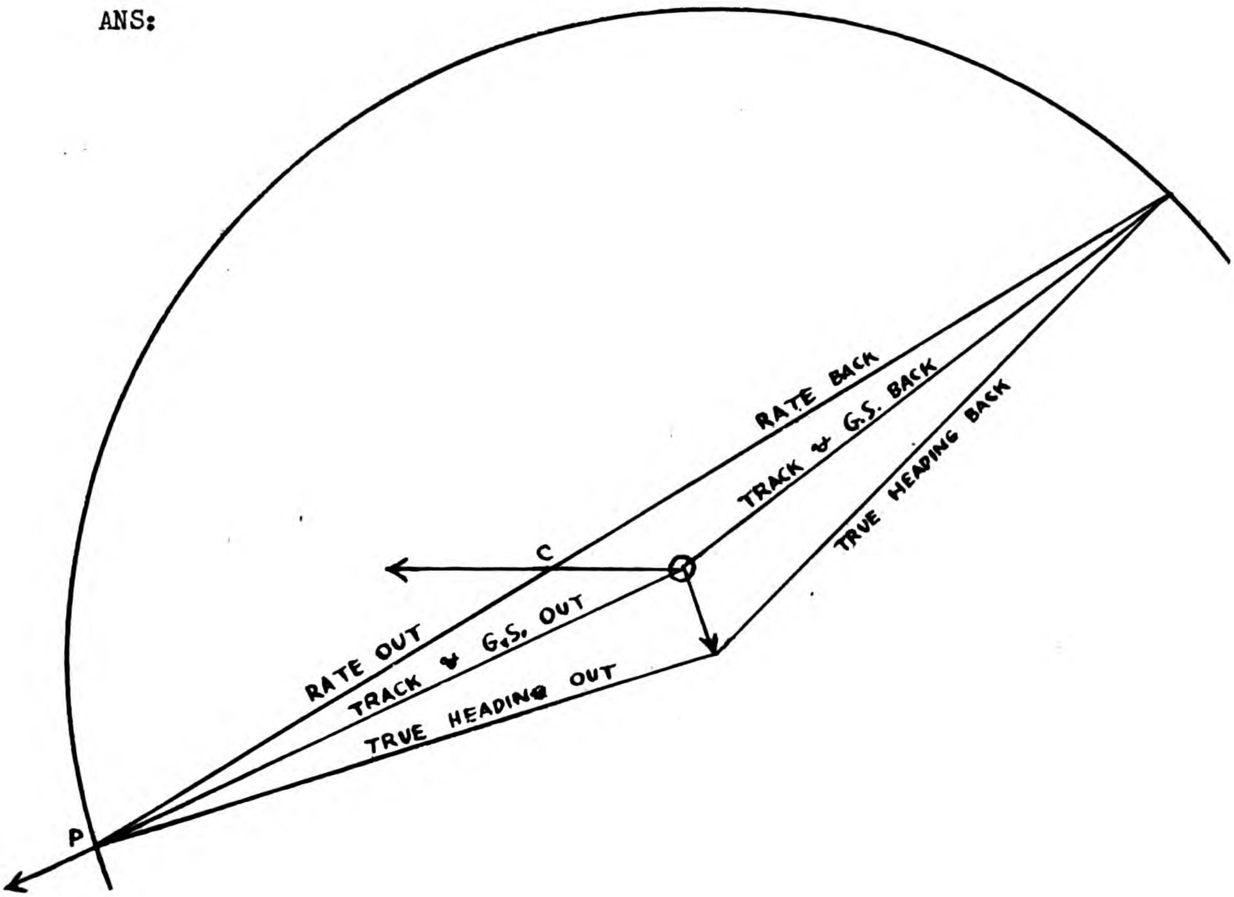
If the distance to the turning point is required, it may be found by multiplying this time by the groundspeed out along the track. In this problem, the groundspeed is 85 kts. so the distance out on the track becomes 270 miles.

EXAMPLE PROBLEM

1. A carrier is steaming west at a speed of 30 MPH. The wind is 340°-20 kts. A plane leaves the carrier on track 245°, with a 4 hour fuel supply (not including reserve). The plane's true airspeed is 140 kts. The navigator has orders to be back at the end of 4 hours.

   Analyze the problem graphically. How long can the plane fly out along track 245° before turning to intercept the carrier. Tabulate all pertinent flight data.

   ANS:



Flight data out		Flight data back	
T.H. 253°	T.A.S. 140 kts.	T.H. 045°	T.A.S. 140 kts.
Track 245°	G.S. 140 kts.	Track 053°	G.S. 133 kts.
	Rate 115 kts.		Rate 157 kts.

The plane should turn back to intercept the carrier after 2.3 hours. At that time the plane will have proceeded 322 miles out along the track.

CLASSROOM PROBLEMS

1. You leave a carrier on track 165° while the carrier proceeds along track 110° at a speed of 30 kts. The wind is 045°-20 kts. Your true airspeed is 120 kts. and you have a usuable 4 hour fuel supply.

   How long can you proceed along your track before turning to intercept the carrier? Show the graphic analysis of the problem and tabulate all flight data.

   ANS:

2. A carrier is proceeding on track 240° at a speed of 20 kts. The wind is north 20 kts. You are instructed to leave on track 270°, scout and return in 3 hours. You leave the carrier at 0630. Your true airspeed will be 120 kts. Show the graphic analysis of this problem and tabulate all flight data. When will you turn to intercept the carrier?

ANS:

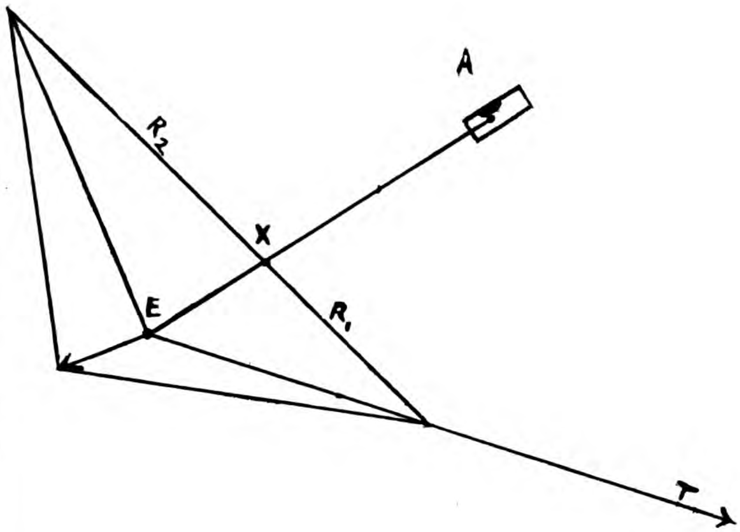
3. A carrier is proceeding on track 000° at a speed of 25 kts. The wind is 030°-15 kts. You are instructed to take off at 1640, scout on track 300° and return to the carrier at 2000. Your true airspeed is 140 kts.

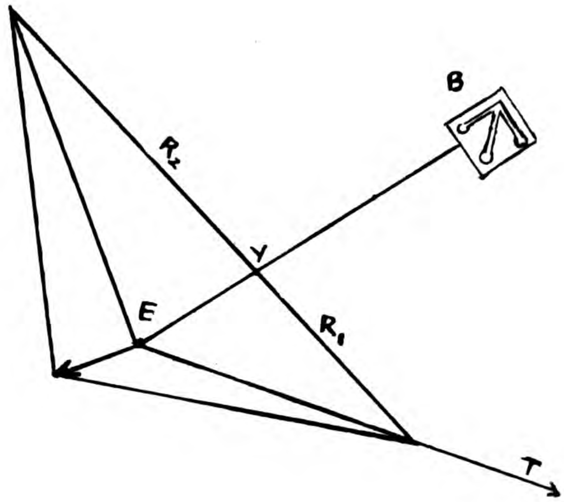
Draw the graphic analysis of this problem and tabulate your flight data. When will you turn to intercept the carrier? How far out along your track will you be when you turn?

ANS:

RADIUS OF ACTION - ALTERNATE BASE

In this problem, the navigator is concerned with the problem as to how long he may proceed toward his destination and still get into an alternate airport if forced to do so. The problem involved is the same as that dealing with operation from a carrier.





Both problems are shown above for comparison. The one at the left is a carrier base problem and that at the right is an alternate base problem.

In each case, the planes flew out along a definite track E-T. In each case the plane could safely remain in flight 3 hours. In each case the navigator knew where a landing runway would be available at the end of that time.

Both navigators had to determine how long they could fly out along track E-T before turning to get to a base not located where their flights commenced.

In the left hand problem, the carrier moved from "E" to "A" in 3 hours, and was at "X" (which is 1/3 the distance E-A) at the end of one hour. The radius of action solution for such a flight has just been discussed.

In the right hand problem the navigator assumed that he took off from a moving field which would be at "B" in 3 hours, and would therefore be at "Y" at the end of one hour. "B" is actually the alternate airport.

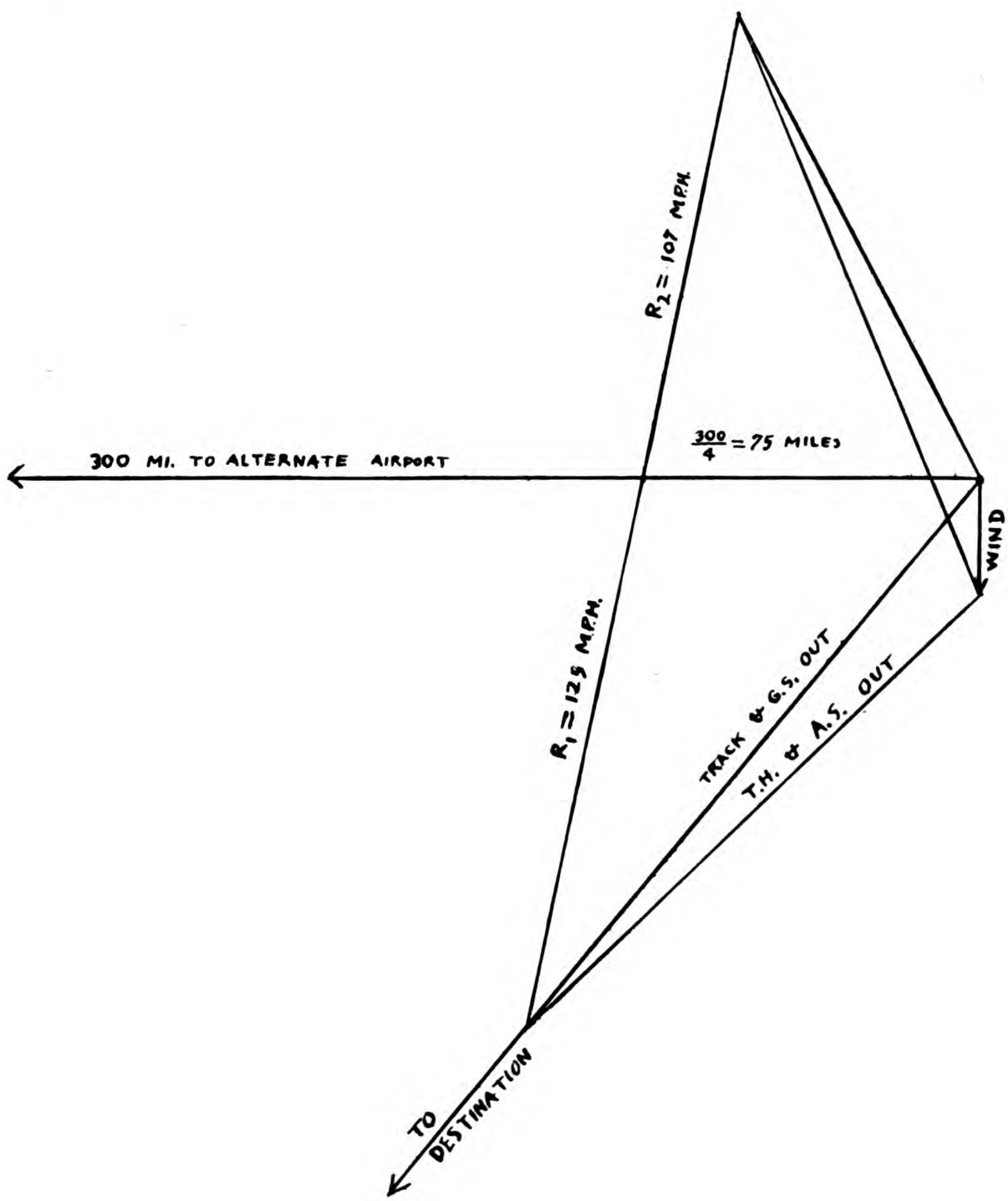
Each navigator then drew identical graphic analyses, and, using R_1 and R_2 determined how long he could proceed out along track E-T before turning off to get to carrier "A" and airport "B" respectively.

EXAMPLE PROBLEM

1. Your true airspeed is 140 MPH. The wind is 000°-25 MPH. You plan to make a 4 hour flight on track 220°. The terminal weather conditions <u>may</u> force you to land at an airport located 300 miles 270° from your starting base.

How long can you proceed toward your destination and still get to the alternate airport without flying more than 4 hours altogether? Diagram the solution of this problem.

ANS:



$$t_1 = \frac{4 \times 107}{125 + 107} = 1.84 \text{ hours}$$

CLASSROOM PROBLEMS

1. Your true airspeed is 120 MPH. The wind is 315°-30 MPH. You plan to make a 5 hour flight on track 155°. Terminal weather conditions may force you to land at an airport located 400 miles south of your starting base.

   How long can you proceed toward your destination and still get to the alternate airport without flying more than the allowable 5 hours?

   Diagram the solution of the problem.

   ANS:

2. Your true airspeed is 160 MPH. The wind is 260°-40 MPH. You plan to make a 6 hour flight on track 160°. Terminal weather conditions may force you to land at an alternate airport located 420 miles 225° from your starting base.

How long can you fly toward your destination and still get to the alternate within the allowable 6 hours? Diagram the solution of the problem.

ANS:

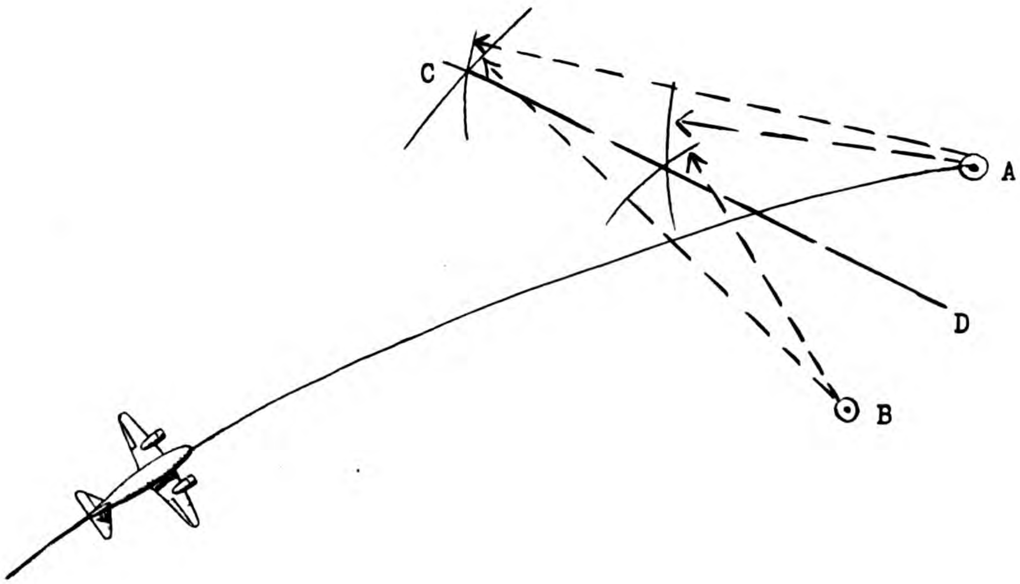
3. Your true airspeed is 150 MPH. The average wind is 270°-20 MPH. You plan to make an 11 hour flight on track 200°. Weather conditions may force you to return to your base.

   How long can you fly toward your destination and still get back to your base within the allowable 11 hours?

   Diagram the solution of this problem.

   ANS:

RADIUS OF ACTION - CHOICE OF NEAREST BASE

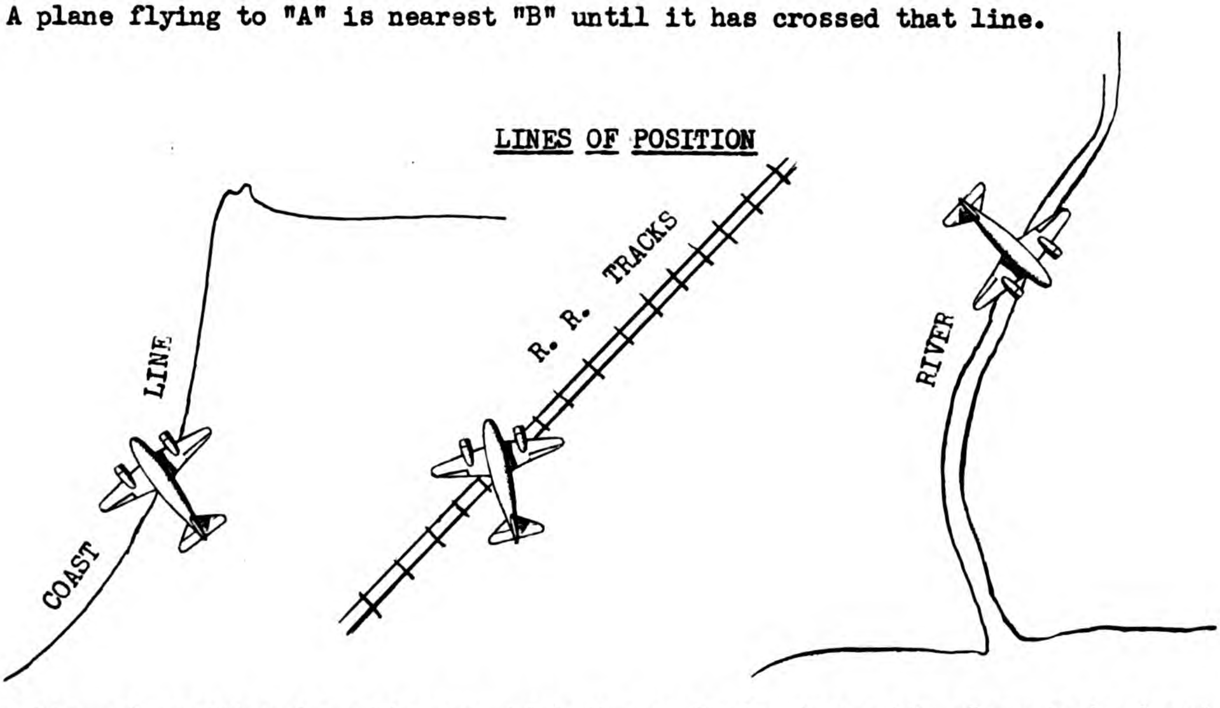


Flight conditions may require a quick decision as to which of two bases is nearest. Such a condition may be anticipated and a diagram such as that above should be drawn in advance.

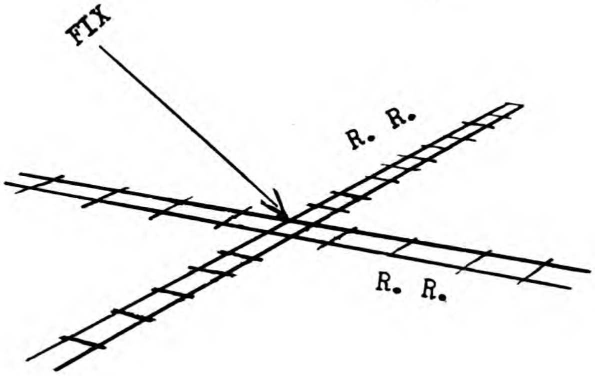
The line C-D is established by joining the intersections of equi-mileage arcs from the two bases "A" and "B".

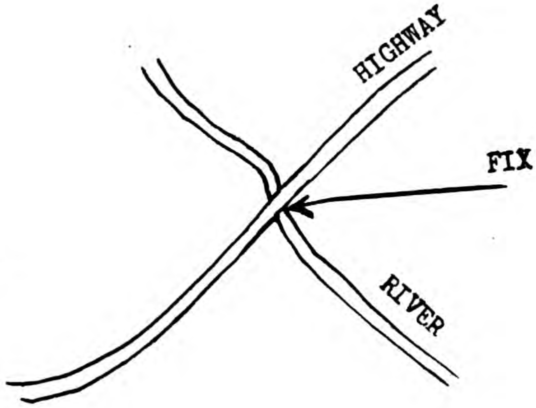
A plane flying to "A" is nearest "B" until it has crossed that line.

LINES OF POSITION

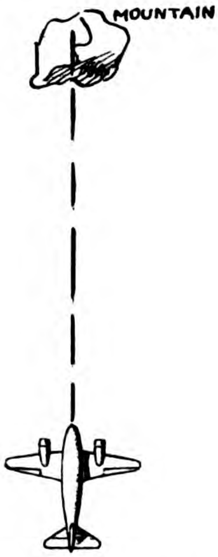


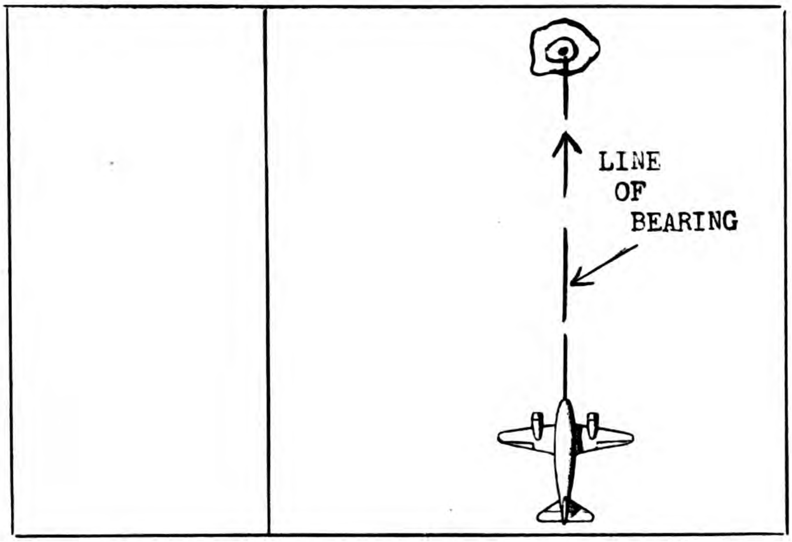
A line of position is a line on which the navigator knows his plane to be located. The illustration above shows several such lines.



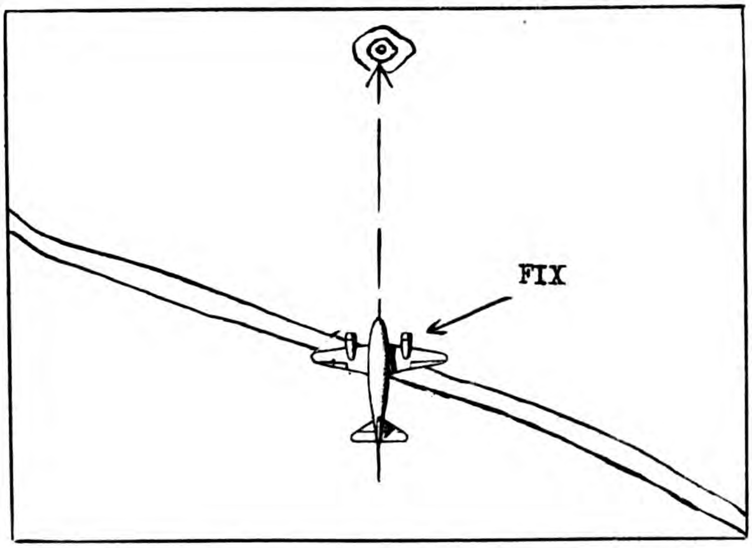


If a navigator locates his plane on two lines of position simultaneously, the plane must be at the intersection of those lines. This is called establishing a <u>fix</u>.

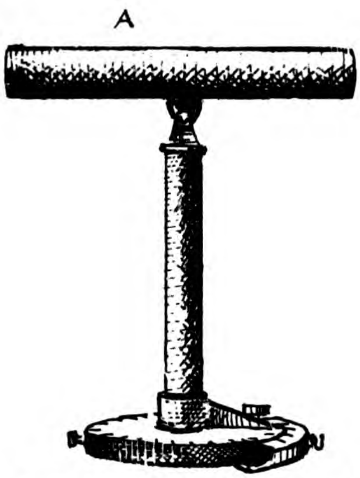


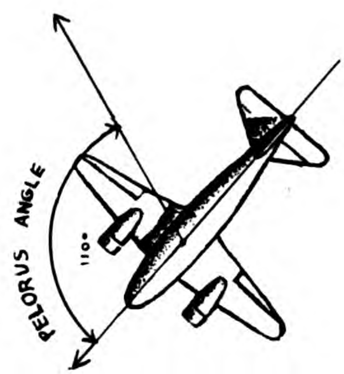


A visual line of bearing is a line of position. In the diagram above, the navigator observes a well known mountain peak bearing true north. The plane must be somewhere on this line of bearing.



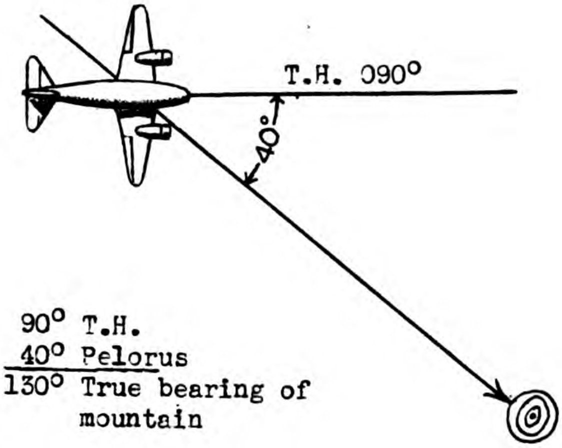
If the plane crosses a well knowh river while the mountain peak bears true north, the position of the plare becomes fixed.

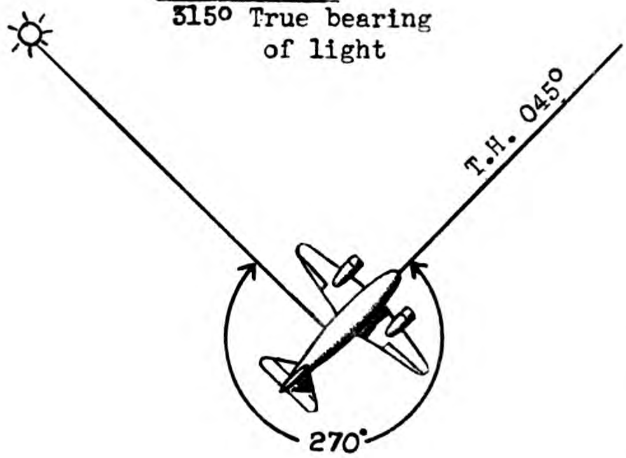




A pelorus such as that shown above is used to take bearings on distant objects. It consists of a telescope "A" mounted in such a manner that it can be turned from left to right and up and down.

The pelorus is <u>not</u> a compass. It only measures angles with respect to the nose of the plane. This angle is measured clockwise from zero to the right.





True bearings are obtained by adding the pelorus bearing to the true heading of the plane.

In the left diagram above, the plane is headed 090° true and the pelorus bearing of a mountain peak is 040°. The true bearing on the peak is 090° plus 040°, making 130° true.

In the diagram at the right, the plane is headed 045° true and the pelorus bearing of an airport beacon is 270°. The true bearing of the airport is 315°.

EXAMPLE PROBLEMS

1. **What is the value of a single line of position?**

   ANS: A single line of position may be enough to tell you whether you are ahead or behind schedule or left or right of your track. It may also be followed until some known landmark is sighted.

2. **Will a single line of position establish a fix?**

   ANS: No.

3. **You are headed 165° true and obtain a pelorus bearing of 175° on a mountain peak. What is the true bearing of the peak from you?**

   ANS: 340°.

4. **You are headed 350° true and obtain a pelorus bearing of 125° on a lighthouse. What is the true bearing of the lighthouse from you?**

   ANS: 350° + 125° = 475° 475° - 360° = 115° True Bearing.

CLASSROOM PROBLEMS

1. Your airport is located on the coastline. The visibility is poor. On your return from a flight to sea, you pass over an unidentified portion of this shoreline. Is this enough information to enable you to turn left or right toward your base?

ANS:________________________________

2. Refer to the problem above. Could you have simplified the navigation problem by deliberately returning to a section of the coast <u>not</u> near your base?

ANS:________________________________

3. You are headed 082° by compass and the error is 17° west. The pelorus bearing of an island is 51°. What is the true bearing of the island from you?

ANS:________________________________

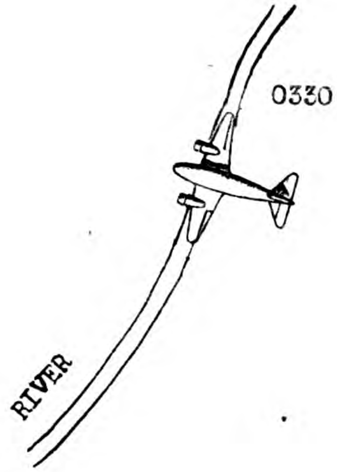
4. You are headed 155° true. The pelorus bearing of a city is 155°. What is the true bearing of the city from you?

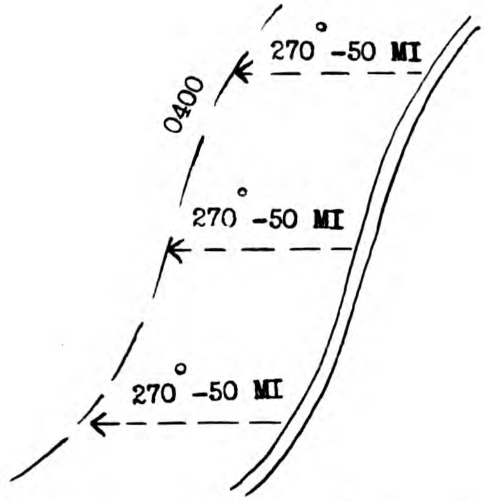
ANS:________________________________

5. You are headed 355° by compass. The variation is 7° west and the deviation is 3° east. The pelorus bearing of a lighthouse is 300°. What is the true bearing of the lighthouse from you?

ANS:________________________________

ADVANCED LINE OF POSITION



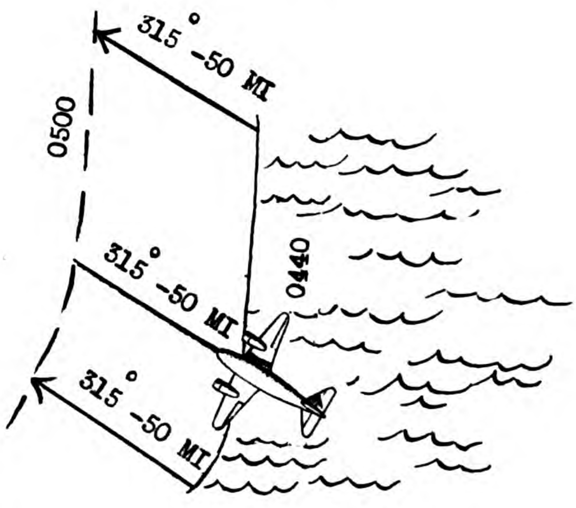


At the left above, a plane is shown crossing a section of a known river at 0330. This establishes a line of position.

After crossing the river, the plane makes a track of 270° and a groundspeed of 100 MPH. No landmark is seen.

At 0400 the plane must be 50 miles west of the river. At the right above, a dotted line shows all possible positions of the plane at 0400.

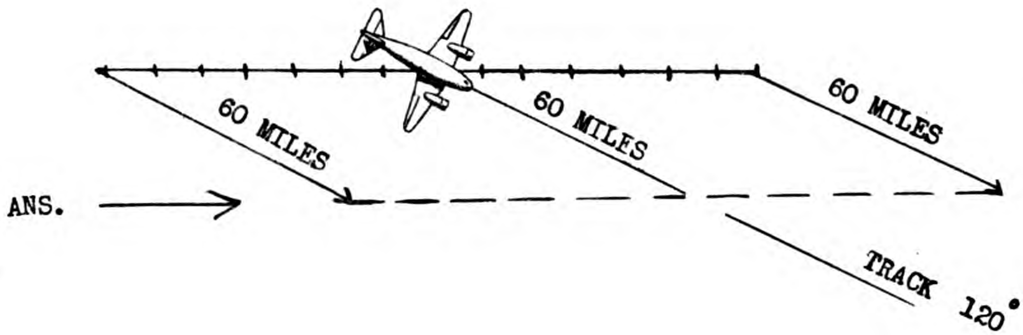
This dotted line is called an <u>advanced line of position</u>.



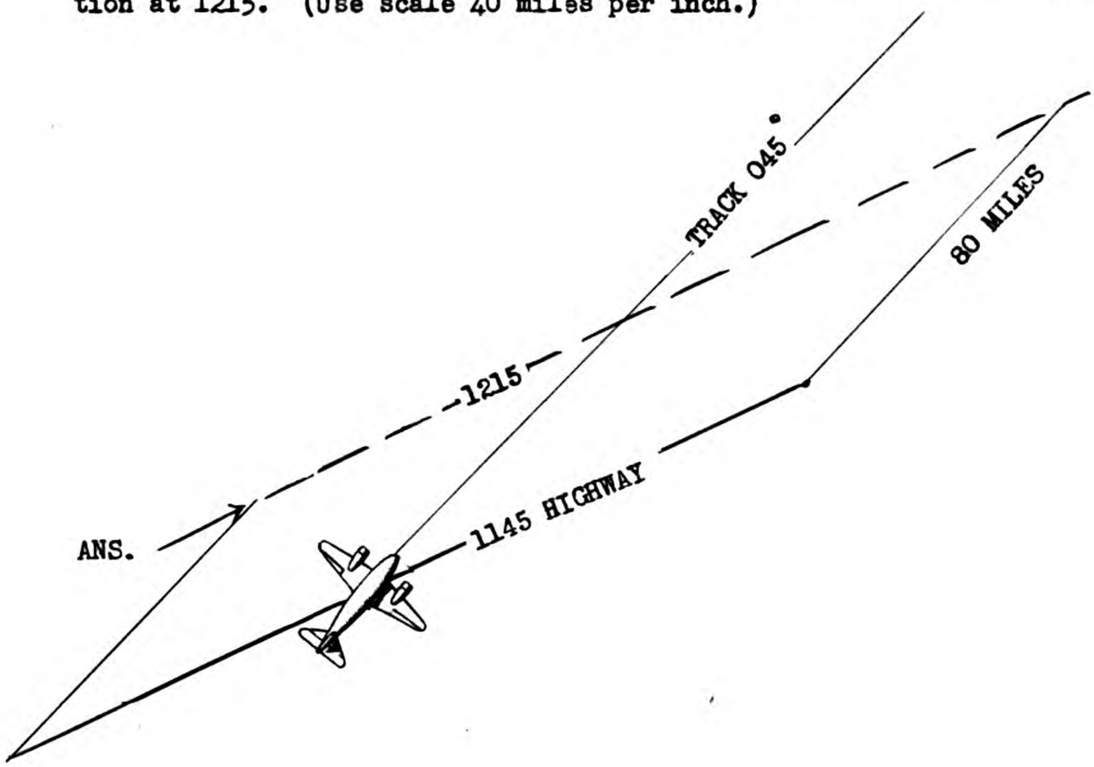
In the diagram above, a plane crossed the coast at 0440 and made a track of 315° and a groundspeed of 150 MPH thereafter. In the absence of further information, the navigator has to assume his plane to be <u>somewhere</u> on the dotted line of position at 0500. <u>The line is always advanced in the track direction</u>.

EXAMPLE PROBLEMS

1. In the following sketch, a plane making track 120°, and groundspeed 120 MPH, crosses the railroad line. Show the possible positions (line of position) of the plane 30 minutes later. (Use scale 40 miles per inch.)



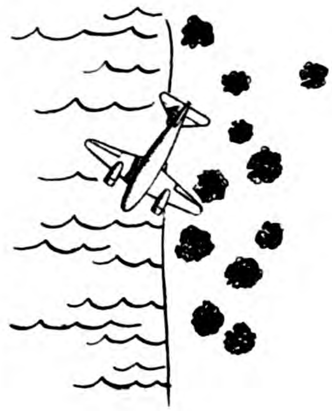
2. In the following sketch, a plane crosses the highway at 1145. The plane is making track 045° and groundspeed 160 MPH. Show the advanced line of position at 1215. (Use scale 40 miles per inch.)



CLASSROOM PROBLEMS

1. In the following sketch, a plane crosses a straight east-west railroad line at 0600. A track of 165° and a groundspeed of 150 MPH is made thereafter. Show the possible positions of the plane at 0725. (use a scale of 40 miles per inch.)

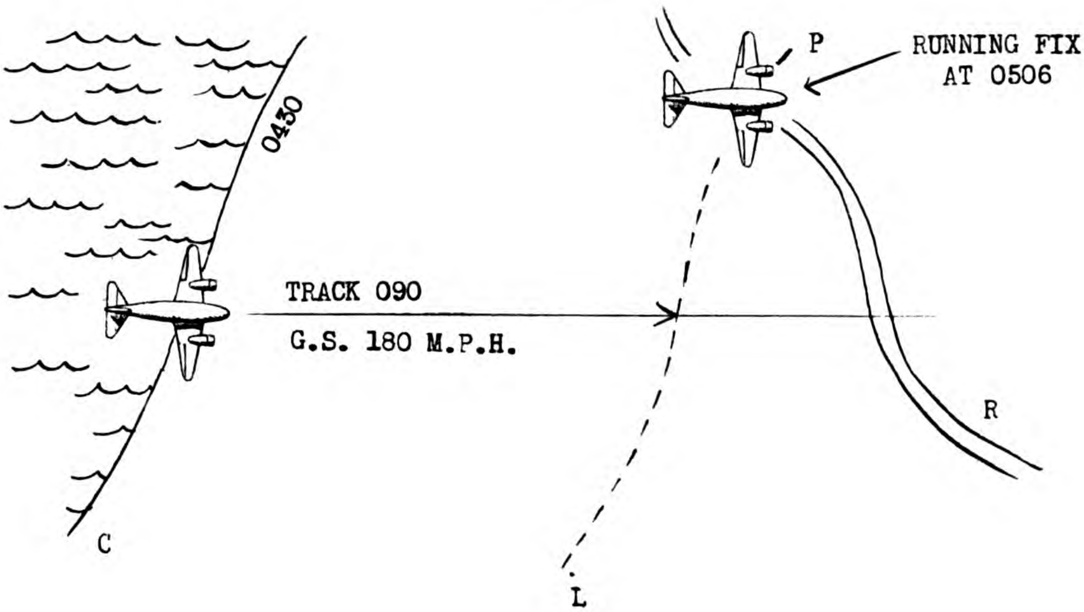
2. In the following sketch, a plane crosses a north-south coastline at 1850. A track of 200° and a groundspeed of 180 MPH is made thereafter. Show the advanced line of position at 1935. (Use a scale of 40 miles per inch.)



3. A plane making track 045° and groundspeed 175 MPH flies out to sea between Jacksonville and Daytona Beach, Fla., at 1145. Show the plane's line of position at 1230. (Use U.S.C.& G.S. chart #3060-B or equivalent.)

4. A plane making track 130° and groundspeed 240 MPH flies out to sea from somewhere between West Palm Beach and Miami, Fla. Show the plane's line of position 30 minutes later. (Use U.S.C.&G.S. chart #3060-B or equivalent.)

RUNNING FIX



If a line of position is advanced to cross another line of position, a running fix is established. In the sketch above, a plane making track 090° and groundspeed 180 MPH crosses the coastline "C" at 0430. At 0506, the plane crossed a river "R". The plane is known to be on the advanced line of position L-P and also somewhere on the river line of position at the same time. It can be only at "O".

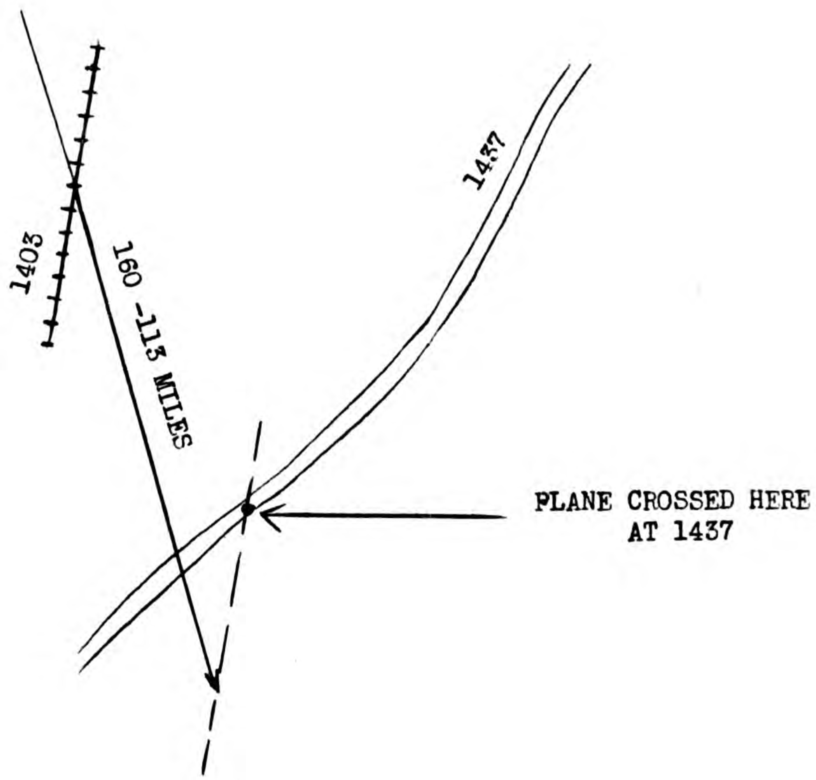
EXAMPLE PROBLEMS

1. How accurate is a running fix?

   ANS: A running fix of this type is as accurate as your knowledge of the plane's track and groundspeed. If the first line of position is advanced too much or too little or along the wrong track, the fix will be in error.

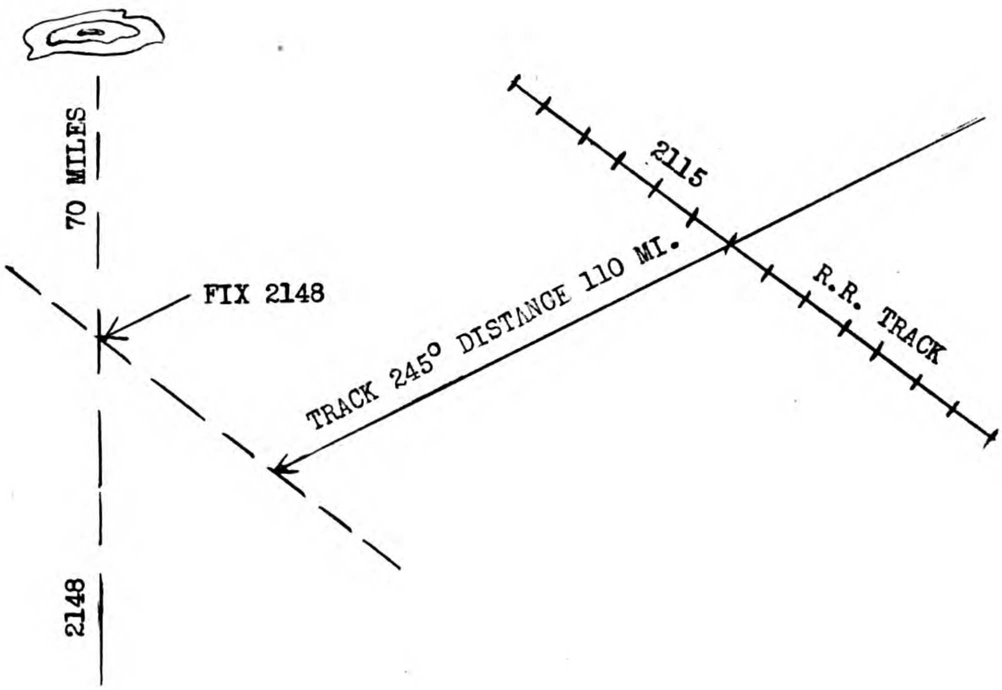
2. In the following sketch, a plane passes over the two lines of position at the times shown. The plane was making a track of 160° and a groundspeed of 200 MPH. Where did the plane cross the second line of position?

ANS:



3. In the sketch below, a plane making track 245° and groundspeed 200 MPH crossed a known railroad track at 2115. At 2150 a well identified mountain peak was found to bear true north from the plane. How far from the mountain peak was the plane at 2150? (Scale 40 miles to the inch.)

ANS:



CLASSROOM PROBLEMS
(Use U.S.C.& G.S. chart #3060-B)

1. You pass over the outer fringes of the coastline between Corpus Christi and Brownsville, Texas on track 230° at 2023. The groundspeed is 180 kts. At 2041 you pass over a large river. How far from Monterrey are you?

ANS:____________________

2. You pass over the coastline between West Palm Beach and Vero Beach, Fla, at 1749 on track 090°, groundspeed 150 kts. At 1821 you catch a glimpse of a large island below you. What is the track to Nassau, Bahama Islands?

ANS:____________________

3. You fly over the northwest shore of Lake Superior between Duluth and Fort William on track 075° at a groundspeed of 180 kts. The time is 1312. At 1400 you pass inland from the lake. How far from Grand Marais are you?

ANS:____________________

4. When you advance a line of position, do you advance it along the track or true heading?

ANS:____

5. When you use the pelorus to aid in the determination of the true bearing of a prominent object, do you add the pelorus bearing to the track or to the true heading of the plane?

ANS:____

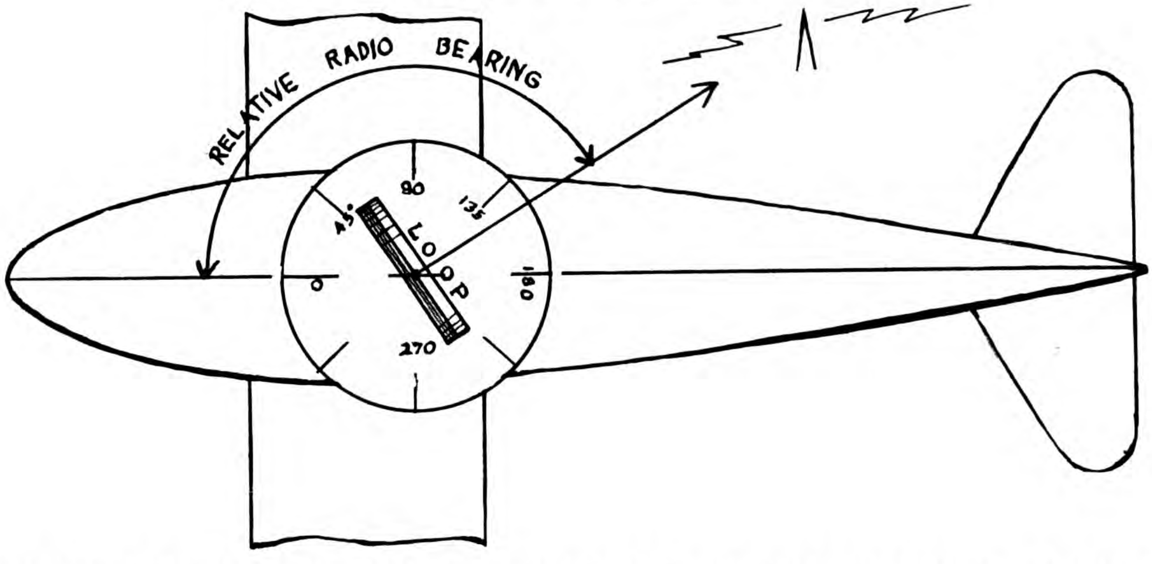
6. The pelorus bearing of a prominent peak is 165°. The compass heading is 355°. The variation is 17° east. The deviation is 3° east. The drift is 14° left. The true airspeed is 140 MPH. The groundspeed is 160 MPH. What is the true bearing of the mountain peak?

ANS:____

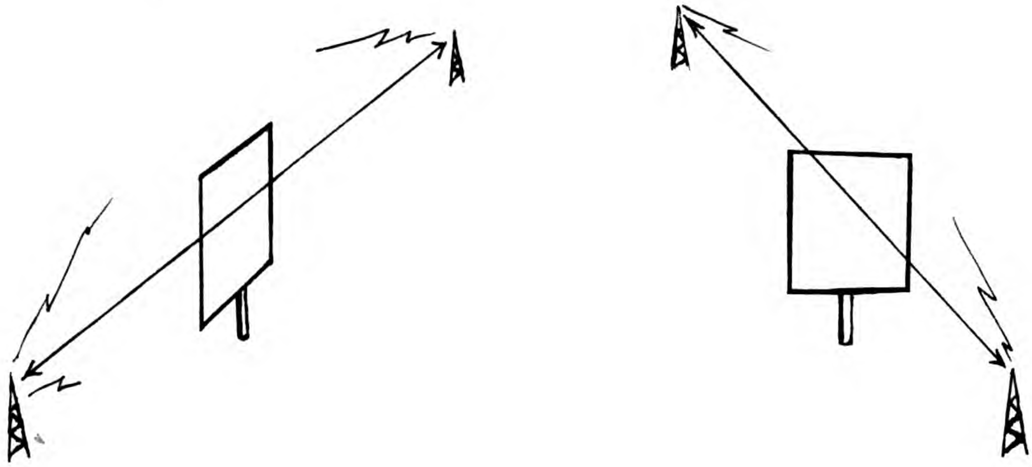
7. Refer to problem 6 above. You wish to advance this line of position for a 30 minute interval. How far and in what direction will the line be advanced?

ANS:____

RADIO LINES OF POSITION - DIRECTION FINDERS



A radio direction finder is used to take bearings of radio transmitting stations. Such bearings, like pelorus bearings, are measured relative to the nose of the plane from zero clockwise to the right.



Radio bearings are obtained through the use of a radio receiver and a rotatable loop antenna. The amount of signal picked up by the loop antenna depends on how it is turned with respect to the transmitting station.

When pointed directly toward or away from the station as at the left above, the loudest signal is heard.

When the loop is rotated either way from these positions, the signal weakens.

With the loop broadside to the transmitting station as at the right above, little or no signal is heard. The no signal point is called the null point.

The null point is easier to detect than the point of maximum signal. The direction finder indicator points toward the station when no signal is heard.

CAUTION: Beware of reciprocal bearings. Maximum signal is heard when either loop edge is pointed toward the station. Minimum signal is heard when either loop face is broadside to the station.

If the transmitted signal is weak the received signal becomes inaudible before the loop is rotated broadside to the station.

At the left above, a bearing is being taken on a weak transmitter. The loop is not at right angles to the station but the signal has disappeared.

At the right above, the loop has been rotated beyond the broadside position to a position where the signal is heard again.

The bearing of the station is considered to be the point midway between these two positions. The width of the null depends on the strength of the transmitted signal, static level, distance from the transmitting station and sensitivity of the bearing-taker's ear.

EXAMPLE PROBLEMS

1. If you were ten miles from a powerful transmitter, how sharp would the null point be?

   ANS: About a degree wide.

2. If you were 300 miles from the same transmitter, how wide would the null be?

   ANS: Under good conditions, it might be as much as 20° wide.

3. Are reciprocal bearings always 180° apart?

   ANS: Reciprocal bearings may not be exactly 180° apart.

4. What is an automatic radio direction finder?

   ANS: It is a direction finder equipped with an electrical "ear" and an associated motor drive which automatically keeps the loop on a null.

5. Will an automatic direction finder take reciprocal bearings?

   ANS: Yes, if the equipment becomes faulty.

6. Is the compass used in conjunction with the direction finder?

   ANS: Yes. The true bearing of the radio transmitter is obtained by adding the relative radio bearing to the true heading of the plane.

7. How much time is required to take a radio bearing?

   ANS: From one to two minutes is required. Watch your compass and direction finder during this interval and use the average indications of each.

CLASSROOM PROBLEMS

1. What is a "null"?

   ANS: ______________________________

2. How is a loop antenna pointed when maximum signals are heard?

   ANS: ______________________________

3. What is a reciprocal bearing?

   ANS: ______________________________

4. How is the direction finder <u>pointer</u> set with respect to the loop antenna?

   ANS: ______________________________

5. Radio stations WBZ, in Boston, Mass., and WBZA, in Springfield, Mass., operate on the same <u>frequency</u> (kilocycles). Would these be good stations on which to take radio bearings? Why?

   ANS: ______________________________

6. Is identification of a <u>radio program</u> sufficient to identify the station from which it is being broadcast? Is the dial setting sufficient?

   ANS: ______________________________

   ____

7. While maintaining a compass heading of 152° (Var. 13° west, Dev. 2° west), you obtain a relative bearing of 002° on the Bermuda transmitter. What is the true bearing of the station from you?

   ANS: ______________________________

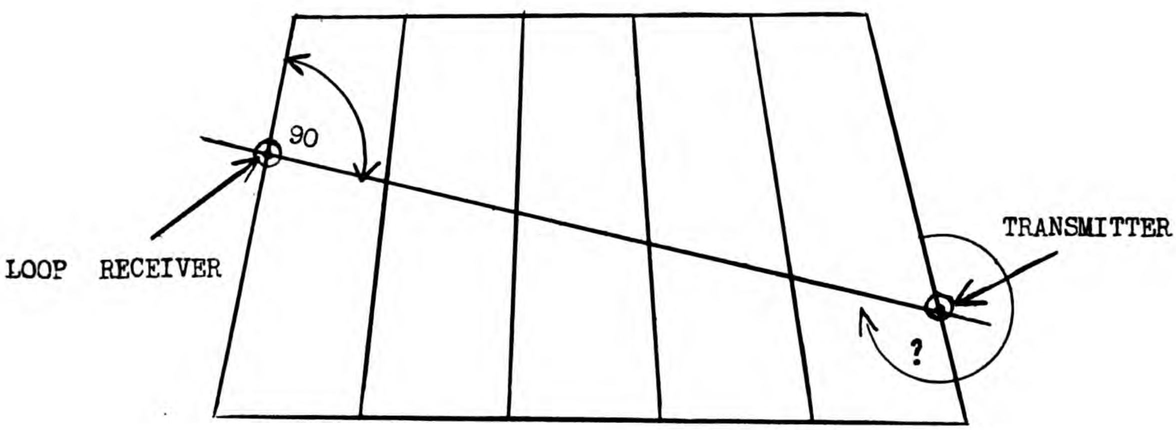
8. While maintaining a compass heading of 353° (Var. 6° east, Dev. 7° west), you obtain a relative bearing of 300° on transmitter WXYZ. What is the true bearing of the transmitter from you?

   ANS: ______________________________

9. While maintaining a compass heading of 179° (Var. 10° west, Dev. 0°), you obtain a relative bearing of 193° on transmitter WABC. What is the true bearing of the transmitter from you?

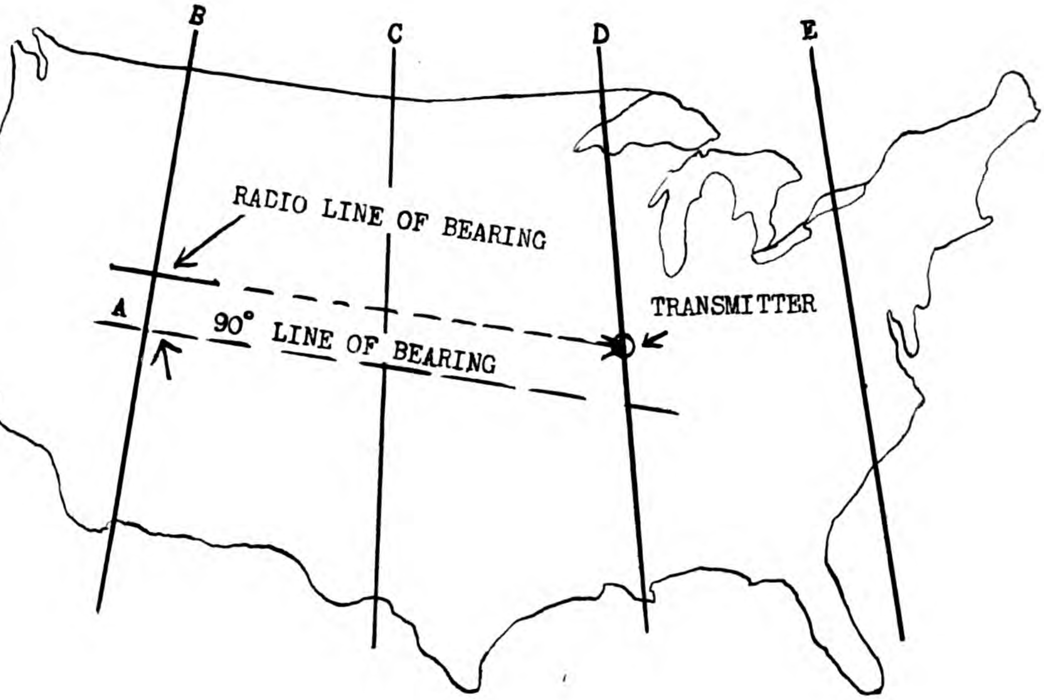
ANS: ______________________________

PLOTTING RADIO BEARINGS - LAMBERT CHART



Radio signals follow the shortest track between transmitter and receiver. Radio bearings are therefore great circle bearings out along this track. If you take a 090° radio bearing, the great circle track (between you and the transmitter) crosses your meridian at an angle of 090°.

Never assume that the signal left the transmitter at an angle 180° opposite from this on his meridian. See the diagram above.



The Lambert Conformal projection of the United States is practically a great circle chart. On this chart a true radio bearing should first be measured on the meridian closest to the bearing-taker's assumed position. See "A" above.

This line of direction should then be moved up or down that meridian until it passes through the transmitting station.

The bearing should always be plotted from the bearing-taker's meridian. (The practice of plotting reciprocal bearings from the transmitter by making allowance for convergence of meridians is not recommended.)

EXAMPLE PROBLEMS
(Use U.S.C.& G.S. chart #3060-B)

1. Is a straight line on a Lambert conformal chart a great circle track?

   ANS: Yes, for all practical purposes.

2. Does the radio signal follow a great circle track?

   ANS: Yes.

3. Is a radio bearing line on a Lambert chart, a line of position?

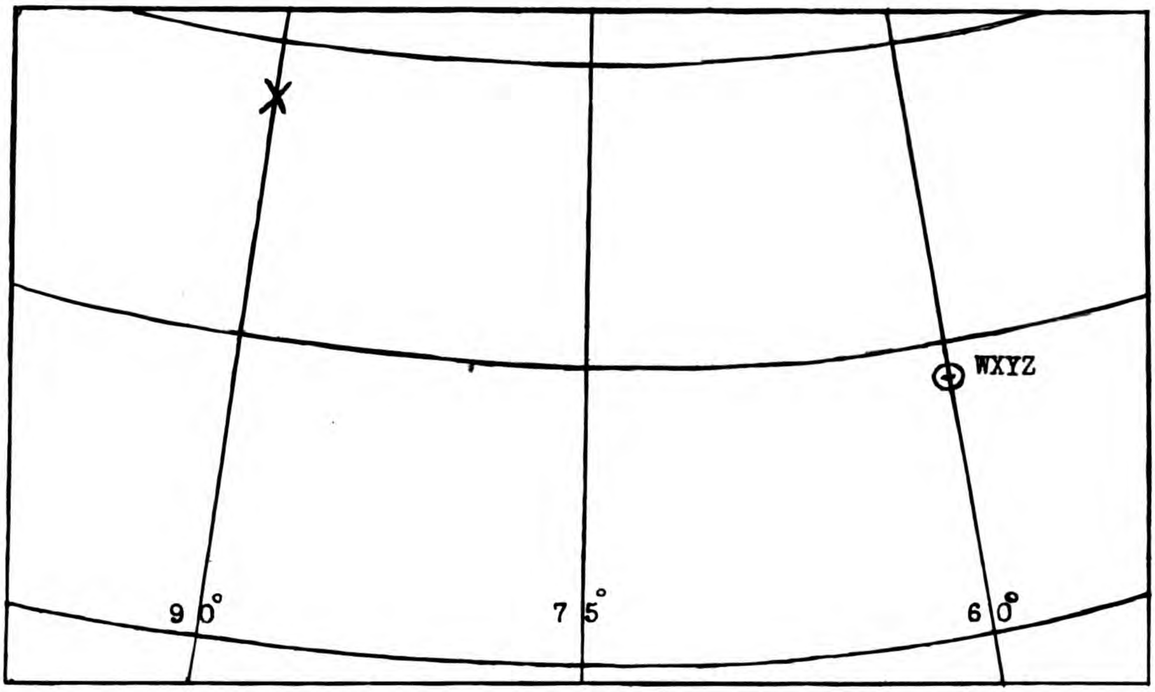
   ANS: Only that portion of the line near the bearing-taker's position can be considered a line of position. Refer to the last diagram. A 090° radio bearing has been taken and has been plotted from meridian "B" on the assumption that the plane was near that meridian. If the navigator had thought himself to be near meridian "C", a different line would have been plotted.

4. How much error would result from plotting a radio bearing from a meridian 100 miles away from your correct position?

ANS: Selection of the wrong meridian in the U.S.A. would, in this case, result in plotting a bearing about one degree in error. If the transmitter were 100 miles away, this one degree error would produce an error of about 2 miles in the line of position.

5. A plane is near meridian "X" below, heading 040° by compass (compass error 7° east). The navigator takes a relative radio bearing of transmitter WXYZ at 0742. This bearing is 020°. Plot the true bearing on the chart below.

ANS:



CLASSROOM PROBLEMS
(Use U.S.C.& G.S. Chart #3060-B or the equivalent)

A plane left Jacksonville, Fla., for Brownsville, Texas at 1040.

1. At 1215 simultaneous relative radio bearings were taken while heading 255° true

Tallahasse	Mobile
160°	060°

Plot the position of the plane.

2. At 1300 simultaneous relative radio bearings were taken while heading 250° mag.

New Orleans	Mobile
047°	110°

Plot the position of the plane.

3. At 1400 simultaneous bearings were taken while heading 245° magnetic.

New Orleans	Lake Charles
148°	061°

Plot the position of the plane.

4. At 1520 simultaneous bearings were taken while heading 230° by compass (Dev. 2° W.).

Brownsville	Houston
355°	102°

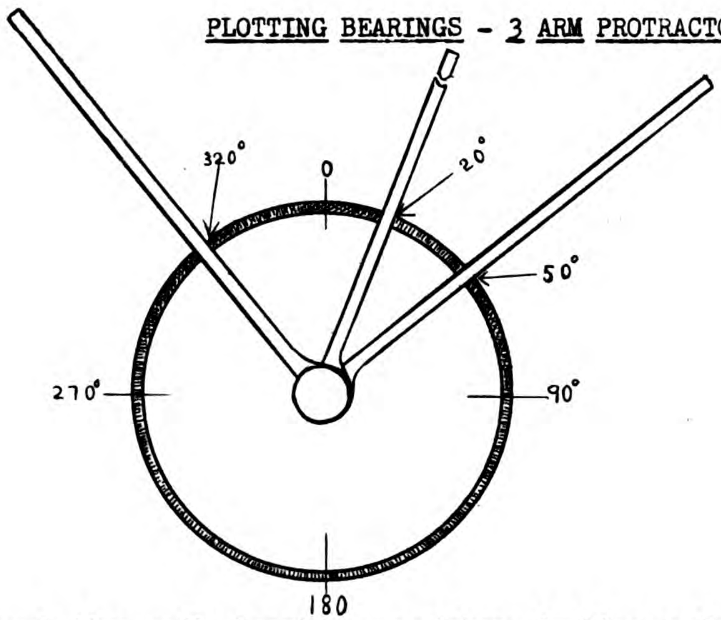
Plot the position of the plane.

5. At 1608 simultaneous bearings were taken while heading 235° by compass (Dev. 2° W.).

Corpus Christi	Brownsville
082°	350°

Plot the position of the plane.

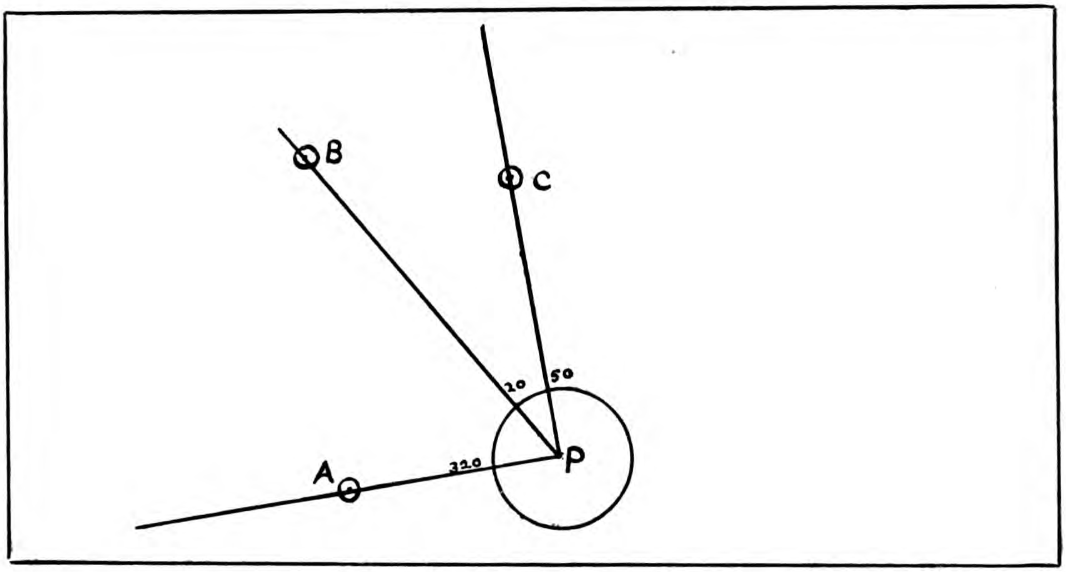
PLOTTING BEARINGS - 3 ARM PROTRACTOR



If three relative radio bearings are taken simultaneously (or nearly so), the position of the plane can be determined without converting the bearings to true bearings.

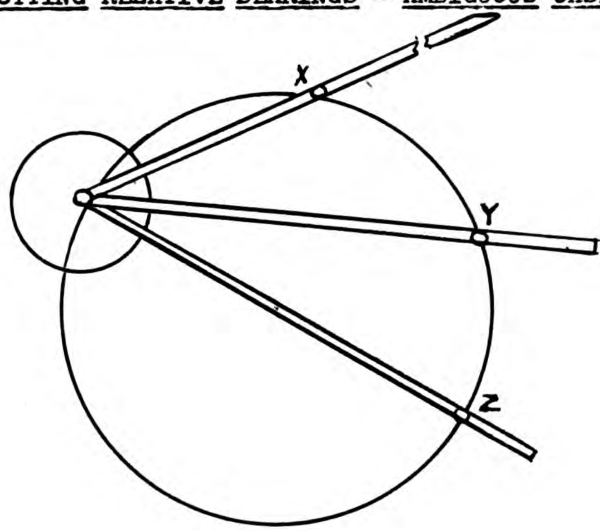
A three arm protractor such as that shown above is used. The arms are set to the angular spread between the relative bearings.

The following relative bearings have been set on the protractor: Station "A" 320°, Station "B" 020° and Station "C" 050°



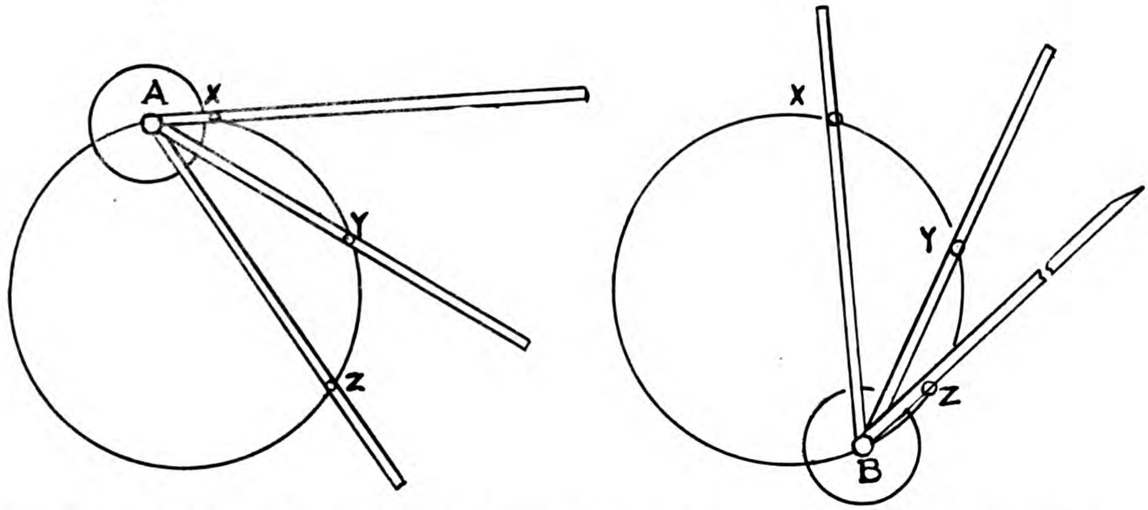
The protractor is then moved around on the chart until the three arms pass through the three transmitting stations. Make sure that the proper arms fall on the correct stations. The plane must be located at "P" because there is but one point from which these related angles could be obtained.

PLOTTING RELATIVE BEARINGS - AMBIGUOUS CASE



CAUTION: The illustration above shows a fix plotted from relative bearings. The fix falls on the circumference of a circle that also passes through the three transmitters.

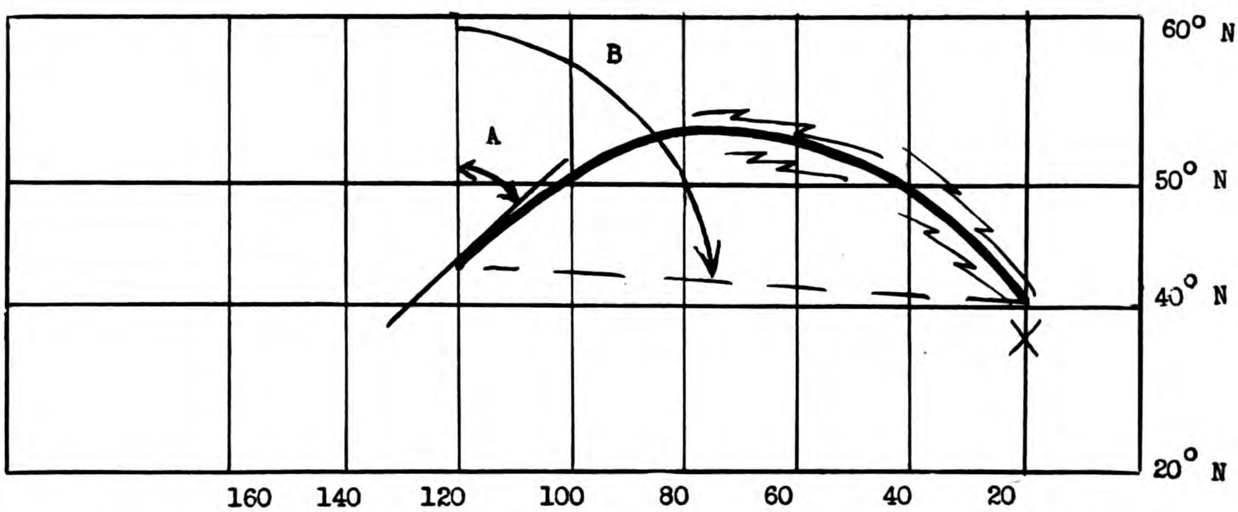
THIS FIX IS ABSOLUTELY WORTHLESS.



The illustrations above show the same three transmitters. The same relative bearings are set on the protractor. The plane could be at "A", "B" or anywhere between "A" and "B".

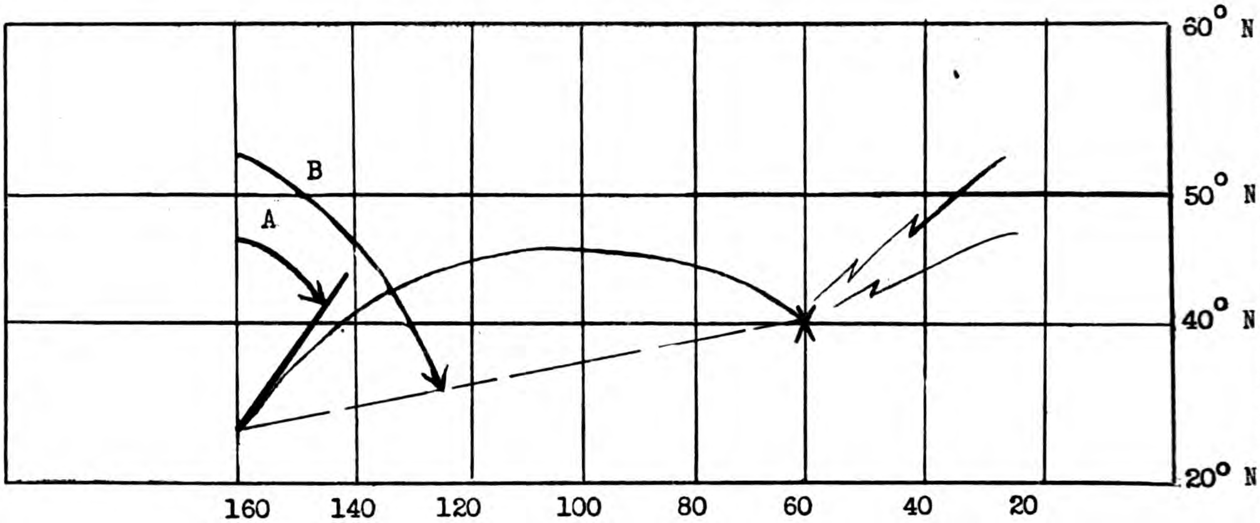
Such ambiguity can be avoided by using true bearings.

RADIO BEARINGS - MERCATOR CHARTS



The great circle track on the Mercator chart above shows the path followed by a radio signal transmitted from "X".

Notice the bearing "A" observed by the navigator. The correct Mercator bearing connecting the receiver and transmitter is the angle "B".



On a Mercator chart, the navigator does not plot the great circle bearing. A correction is applied to the great circle bearing that changes it to a mercator bearing. The mercator bearing thus obtained is plotted.

In the diagram above, bearing "A" was taken but bearing "B" was plotted.

MERCATOR RADIO BEARINGS

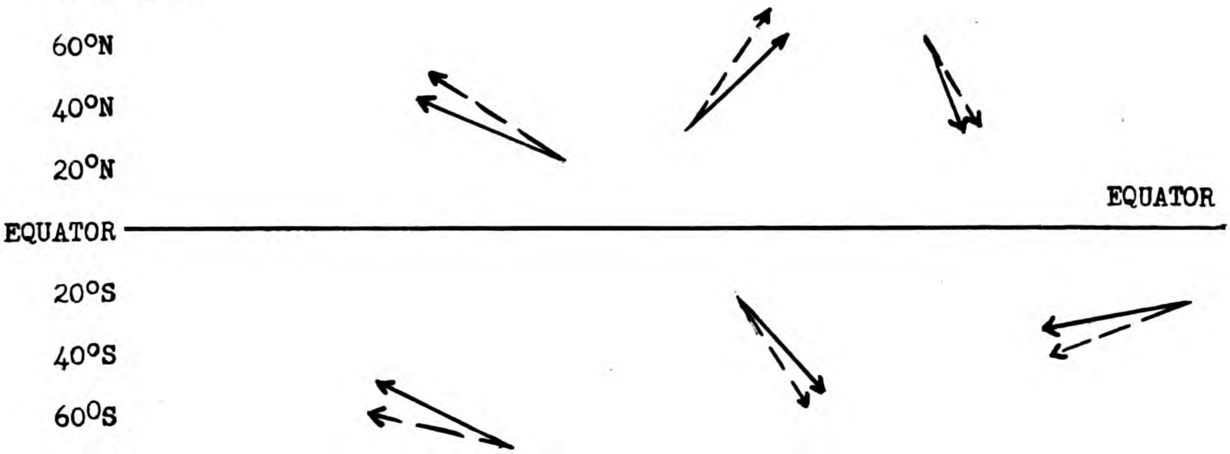
	DIFFERENCE IN LONGITUDE					
Mid. Lat.	1	3	6	9	12	15
10	.1	.2	.5	.8	1.0	1.3
20	.2	.4	1.0	1.5	2.1	2.6
30	.2	.6	1.5	2.2	3.0	3.8
40	.3	.8	1.9	2.9	3.9*	4.8
50	.4	1.0	2.3	3.4	4.6	5.8
60	.4	1.1	2.6	3.9	5.2	6.5
70	.5	1.4	2.8	4.2	5.6	7.1

The correction to be applied to the true great circle bearing depends on the middle latitude between transmitter and receiver and, also, on the difference of longitude between the two stations.

The table above shows the amount of the correction for various combinations of mid-latitude and difference of longitude.

If the transmitter is in Lat. 50° and the bearing-taker is in Lat. 30°, the mid-latitude is 40°. If the transmitter is in 60° Longitude and the bearing taker is in 48° Longitude, the difference is 12°.

Under this condition, a correction of 3.9° must be applied to the bearing on the transmitter.



The correction is always applied in such a manner that the plotted bearing points a little more toward the equator. In the diagram above, the dotted lines are uncorrected great circle bearings.

The solid lines are the plotted mercator bearings.

EXAMPLE PROBLEMS

1. A navigator requests Bermuda to take a bearing on his plane transmission. Bermuda advised him that his true bearing is 060° from Bermuda. Can the navigator plot this bearing as it stands?

   ANS: No, not until the navigator applies the mercator correction.

2. The position of Bermuda is approximately Lat. 32° N., Long. 65° W. The navigator assumes the plane is near Lat. 40° N., Long. 55° W. What bearing should he <u>plot</u> from the data in question #1 above?

   ANS: The correction to be applied to the 060° bearing is 3°. The navigator should plot a bearing of 063° from the direction finder at Bermuda.

3. Why is the correction small in low latitudes?

   ANS: Great circle tracks and mercator tracks are nearly the same near the equator.

4. A plane near Nantucket Shoal is heading 173° by compass (Dev. 3° west). The navigator takes a relative radio bearing of 355° on Bermuda. What bearing must be plotted through the Bermuda transmitter?

   ANS: 151.5°.

5. What does the international abbreviation QTE mean?

ANS: QTE means: Your true bearing from me is --- degrees.

6. Should the mercator correction be applied at the station or plane?

ANS: The question is vague. Radio bearings involve a transmitter and a direction finder. The true bearing obtained at the D.F. station cannot be plotted until <u>somebody</u> applies the mercator correction to it.

If you use the plane's D.F. you will naturally apply the mercator correction yourself because only you will know how much to apply.

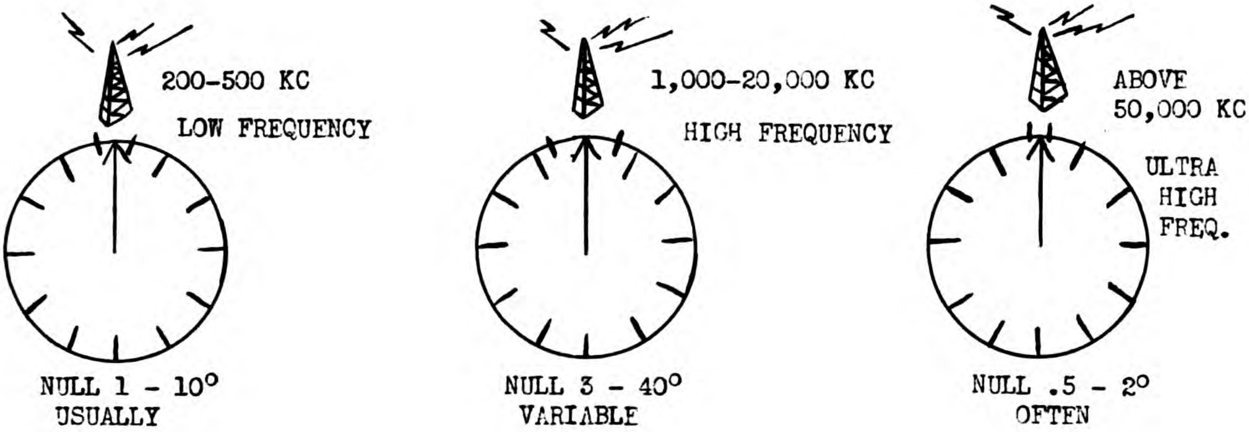
If you request some other D.F. station to take a bearing on your transmitter, you will be supplied with an uncorrected true bearing from them to you. <u>You</u> will have to apply the correction to their bearing because only you will know how much to apply.

7. You are near Cape Hatteras. Bermuda sends you the following: QTE 285°. What mercator bearing must be plotted?

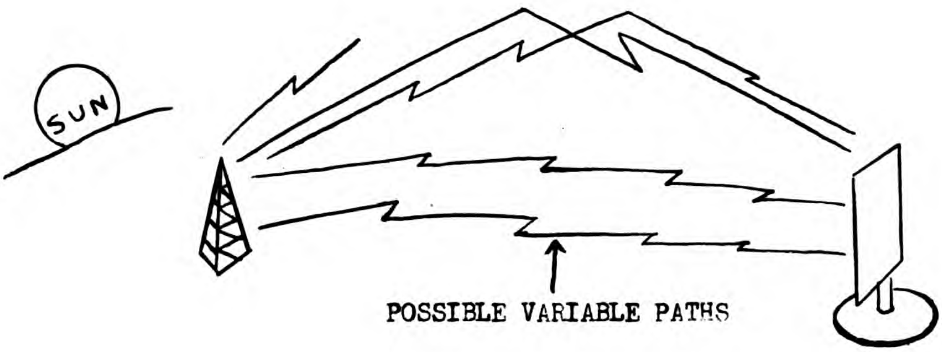
ANS: 282°

ACCURACY OF RADIO BEARINGS

A weak signal contributes to inaccuracy of radio bearings because the null is too wide to permit accurate determination of the null point.

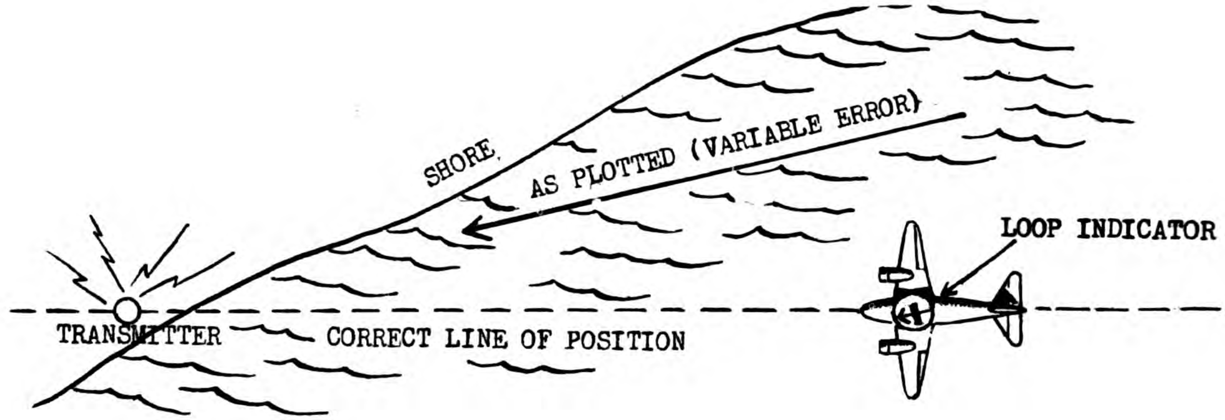


Bearings taken on high frequency transmitters are not as consistently reliable as bearings taken on low frequency transmitters. Very good results, however, are being obtaaned with ultra high frequency transmitters.

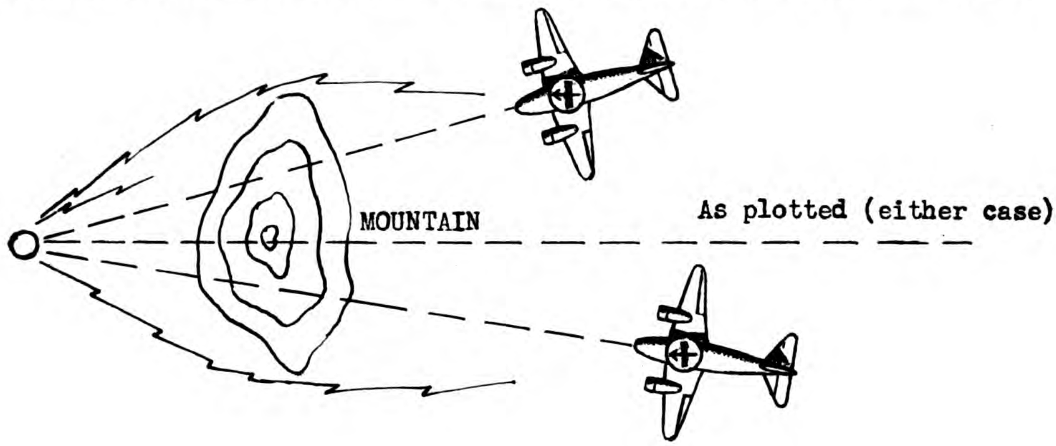


Bearings taken shortly before or after sunrise and sunset are usually very unreliable.

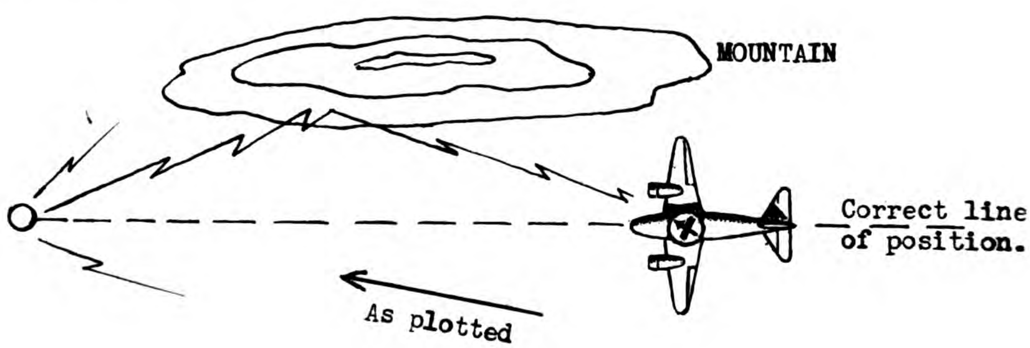
This unreliability may extend into the night to a greater or lesser degree. It is then classified as night effect. Instead of ground waves coming directly from transmitters, many waves are reflected from high above. This causes nulls to wander or be obscure.



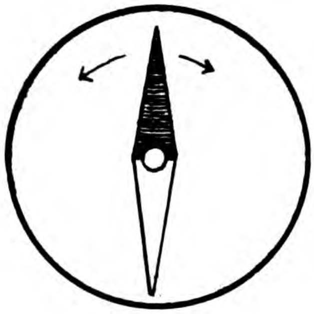
Radio bearings that parallel a long coastline are usually somewhat in error. The plotted bearings show the plane closer to a shore than it actually is.



Radio signals are frequently found to bend around mountain peaks. Bearings taken on a station behind a mountain are usually unreliable.

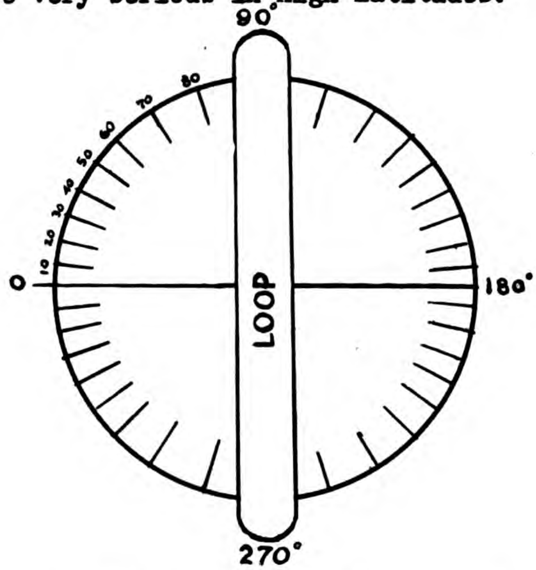


Radio signals are reflected from nearby sides of hills and mountains and bearings taken near such terrain should be used with caution. Near such terrain bearings become very erratic.



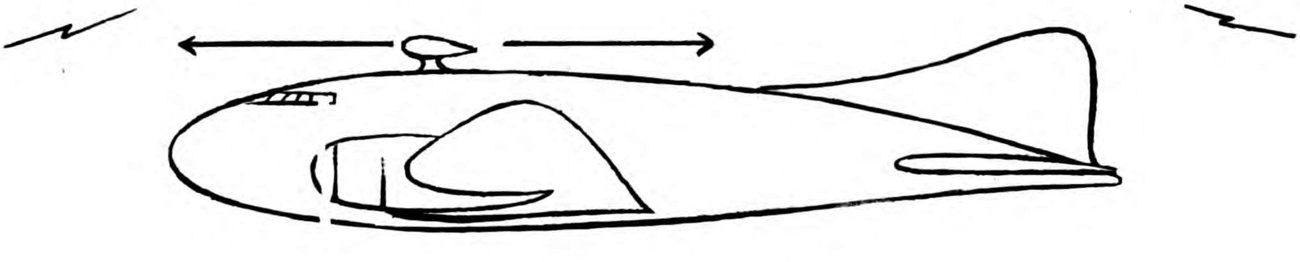
Sluggish Compass
Slow Movement.

Though the relative radio bearing may be good, the final true bearing may be several degrees in error unless extreme care is taken in reading the magnetic compass. This can be very serious in high latitudes.

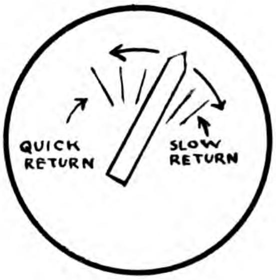


The loop antenna is rotated by a small wheel or crank. The circumference of this wheel is graduated in degrees. These markings are not regularly spaced as in the case of a compass rose. The irregular spacing of these graduations makes provision for certain errors in the loop itself.

Very careful reading of the loop becomes necessary where these markings are crowded together. Some loops are provided with mechanical compensators. In this case, the rose is evenly calibrated. Other loops with even graduations and no compensator use a correction chart.



Bearings taken over the nose and tail are equally reliable. This has been questioned in the past.



If an automatic direction finder becomes sluggish, it should be used with caution as signals may be weak or the instrument unreliable. Be especially cautious if it is more sluggish on one side of the bearing than the other.(See left above.)

If the automatic D.F. swings wildly from side to side, the signals are erratic (night effect) or static may be heavy. There may be times when you will be forced to average out widely different readings but the resulting bearing should be used with caution. (see right above.)

CLASSROOM PROBLEMS
(Use H.O. chart #VP 102 or the equivalent)

1. Your approximate position is Lat. 42°N., Long. 64° W. You receive a QTE of 107° from station NAB. Plot the radio line of position.

2. Your approximate position is Lat. 38°N., Long. 72° W. You receive a QTE of 169° from station NJY. Plot the line of position.

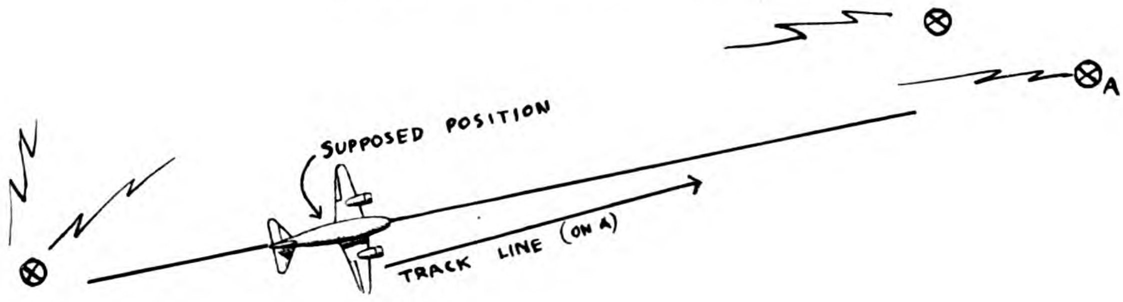
3. Your approximate position is Lat. 38°N., Long. 73° W. You receive a QTE of 060° from station NCZ. Plot the line of position.

4. Your approximate position is Lat. 35° N., Long. 72° W. You receive a QTE of 295° from VRT. Plot the line of position.

5. Your approximate position is Lat. 32° N., Long. 78° W. You are steering 040° by compass (Dev. 2° E.). You obtain a relative radio bearing of 355° on Diamond Shoal radio beacon. Plot the line of position.

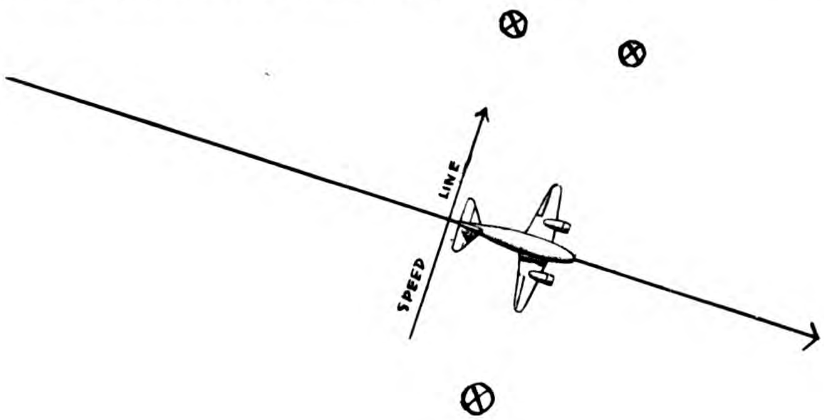
6. Your approximate position is Lat. 40° N., Long. 65° W. You are heading 090° by compass (Dev. 2° E.). You obtain a relative radio bearing of 210° on Nantucket Shoal beacon. Plot the line of position.

USE OF SINGLE LINES OF POSITION



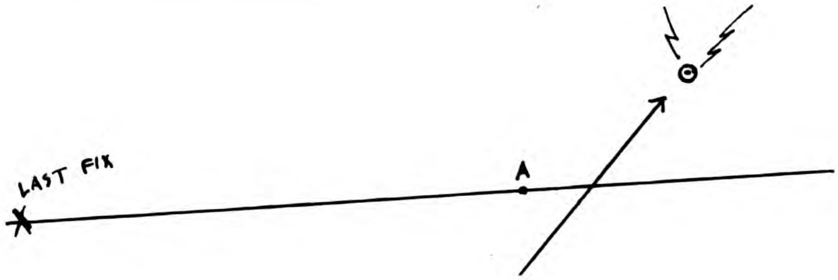
In the illustration above, the navigator may obtain lines of position from any or all three radio stations. There is not enough spread between stations to enable him to establish a good fix.

In such a situation, the navigator may use the station thought to be directly ahead of or behind him and, by means of a line of position, establish the plane's track. The position of the plane on this track line will depend entirely on the navigator's assumption of the plane's groundspeed.



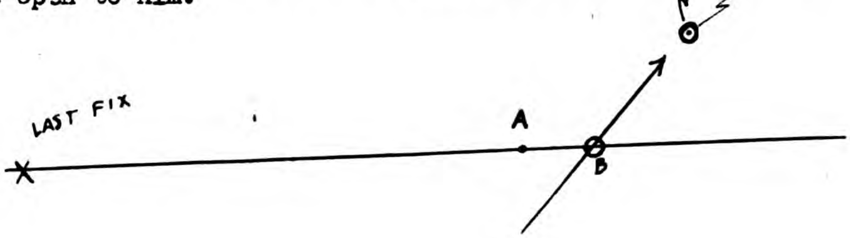
In the illustration above, several stations are grouped too closely together to enable the navigator to establish a fix. However, by taking bearings on the station nearest right angles to the track, a line of position across the track will be obtained and the navigator will get a good idea of the plane's groundspeed.

The position of the plane on this line will depend on the navigator's knowledge of the track made good from the last fix.

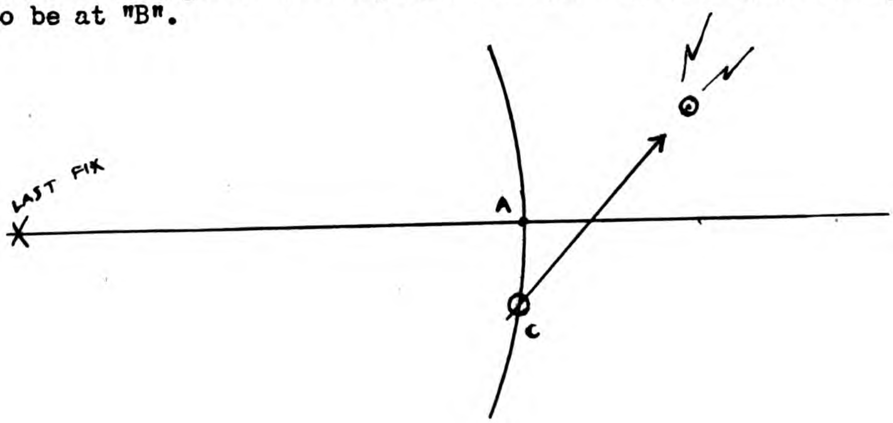


In the illustration above, the navigator has laid down a line of position that neither parallels the track or cuts across it at right angles. It is neither a speed line nor a track line.

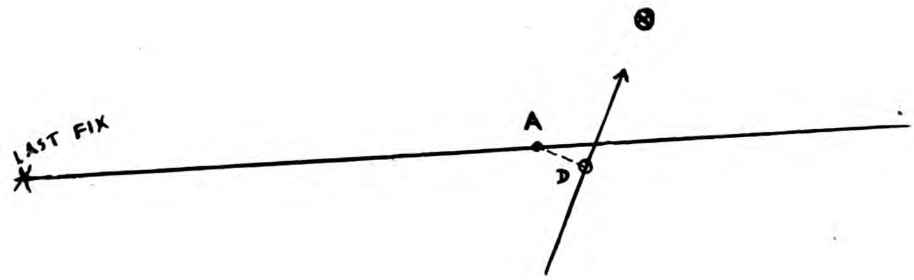
When the bearing was obtained, the navigator believed his plane to be at "A". The radio station is close enough to the track so that there is no question in the navigator's mind as to the accuracy of the line. Four possible lines of proceed-ure are open to him.



He may have knowledge as to the plane's track. In this case he may assume the plane to be at "B".

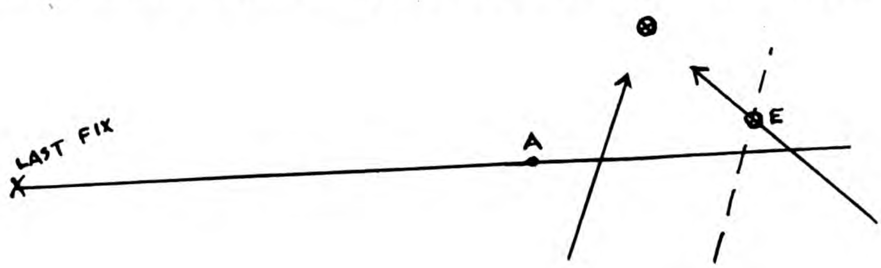


He may have an excellent idea as to the plane's groundspeed; if so, he should swing an arc equal to the distance travelled from the last fix (as above) and the plane must be assumed to be at "C".



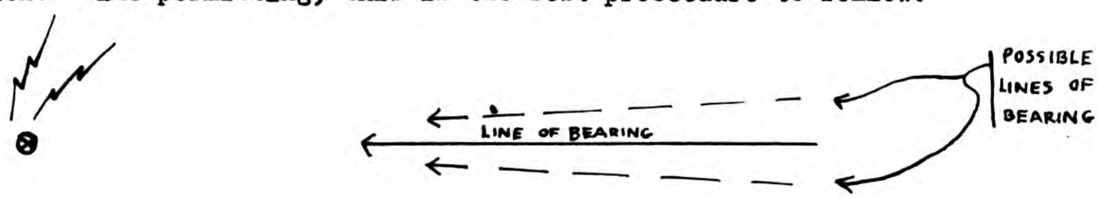
If the navigator has no better idea of his track than groundspeed, he should reason as follows:

To the best of his knowledge, the plane should be at "A". The plane, however, must be on the line of position. The point on the line of position nearest "A" is the most probable position of the plane. See "D" in the diagram above.



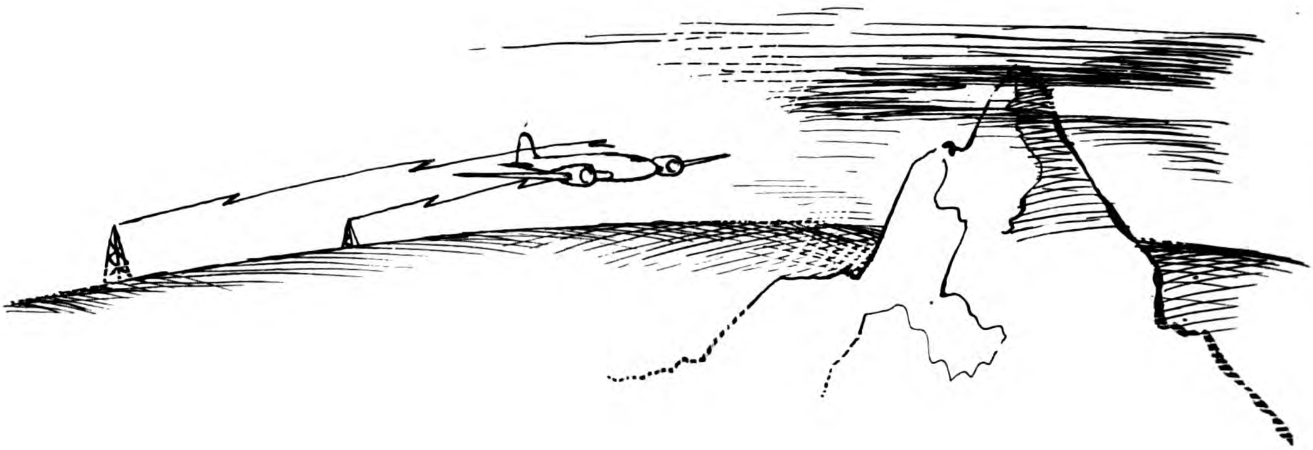
In the illustration above, the line of position is shown plotted as before. In this case, the navigator elected to wait until a second line of position could be laid down from the same station.

The first line is shown advanced to obtain a running fix at "E" on the second line of position. Time permitting, this is the best proceedure to follow.

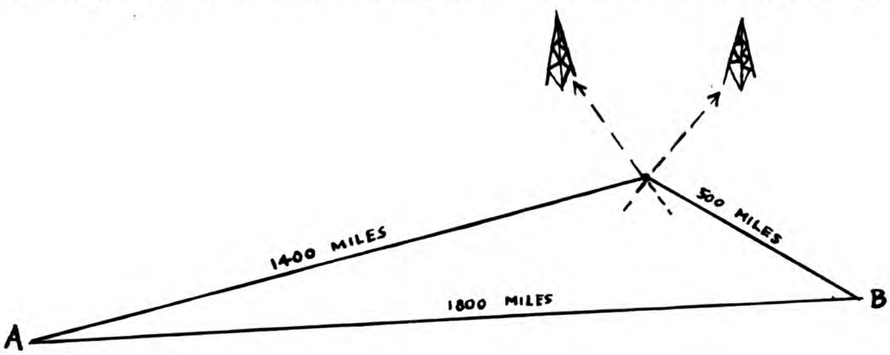


If the navigator believes that a certain error (say 5^o) exists in a line of bearing, he should plot a bearing 5^o either side of the original bearing and assume that the plane could be between the inner and outer possible bearings. See the sketch above.

USE OF FIXES



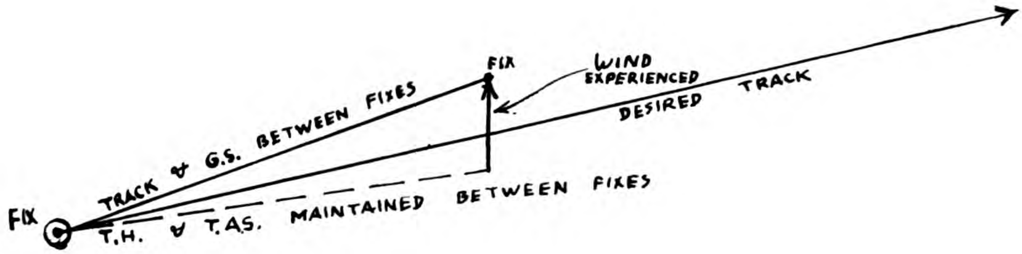
The mere establishment of a fix is often important in itself. In the diagram above, the navigator has located his plane and found it dangerously close to high terrain.



The establishment of a fix is the only sure way to obtain information regarding the track made good and the distance made good toward the destination.

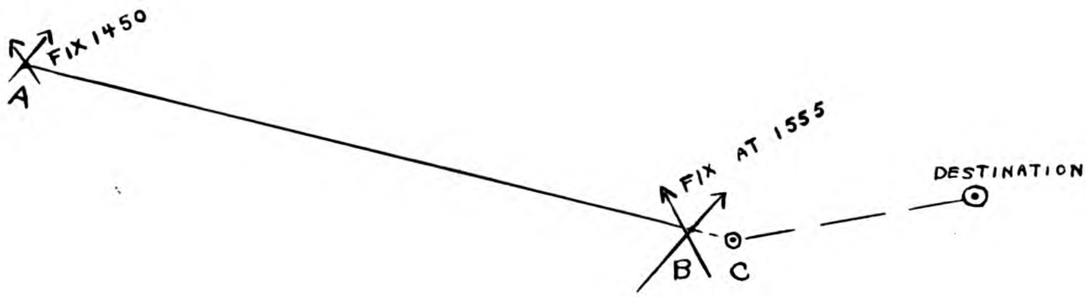
In the diagram above, the total distance from "A" to "B" is 1800 miles. The fix shows the plane to be 1400 miles from the starting point, but it also shows that a distance of 500 miles remains to be flown.

As far as distance toward the destination is concerned, only 1300 miles has been made good. (1800 - 500 = 1300)



The track and groundspeed made good between two fixes is sufficient information (when used in conjunction with the true heading and airspeed maintained) to enable the navigator to determine the average wind experienced.

There is no assurance that this wind will continue to act on the plane, but knowledge of the past wind <u>may</u> enable the navigator to predict the wind in the next zone.

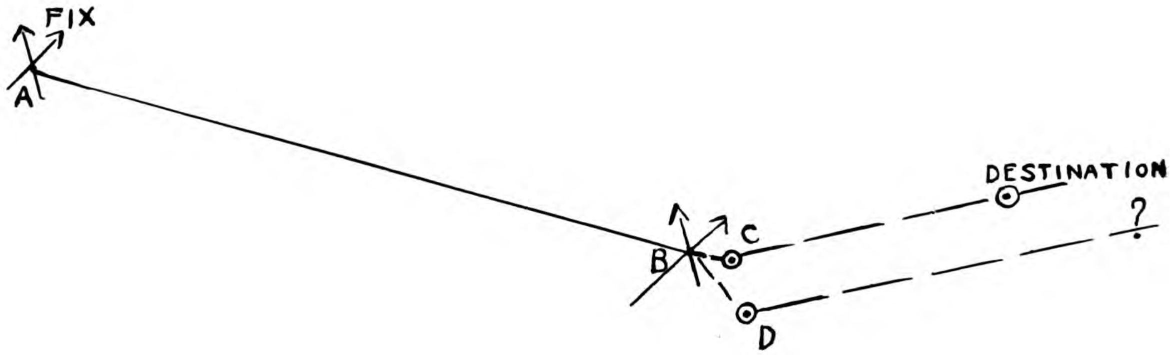


Because the plane flies on while a fix is being plotted and the wind determined, the new track is not laid down from the fix itself.

After plotting the fix, study the flight data which it supplies. Next determine where the plane will be when you change the track, and figure out new compass headings from <u>that</u> position.

In the diagram above, the plane at 1450 was at "A". At 1555 the plane was at "B". It took the navigator 5 minutes to determine the track, groundspeed, wind experienced and anticipated wind.

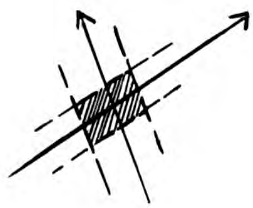
By that time, the plane had advanced 15 miles! The new track was, therefore, laid down from "C" 20 miles beyond the fix, which allowed time to determine and change heading.



In determining the track and groundspeed between fixes, the navigator must recognize that, at the time of taking the second fix, the plane might have been traveling faster (or slower) than the average groundspeed.

Also, the plane may not have been traveling along the track connecting the two fixes.

For this reason, the advanced position "C" may be in error, and this fact should be carefully considered when laying down the new track. Instead of being at "C" above, the plane may have been at some point such as "D" when the heading was changed.



When the navigator assumes errors in lines of position that are used to establish a fix, he must plot these errors as above and recognize that the plane could be anywhere in the shaded area.

EXAMPLE PROBLEMS

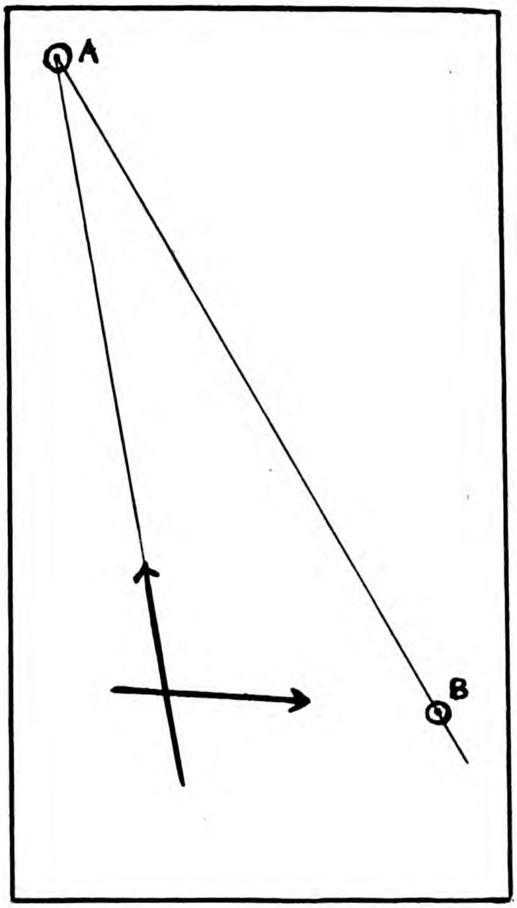
1. Is it possible to plot magnetic radio bearings instead of true radio bearings?

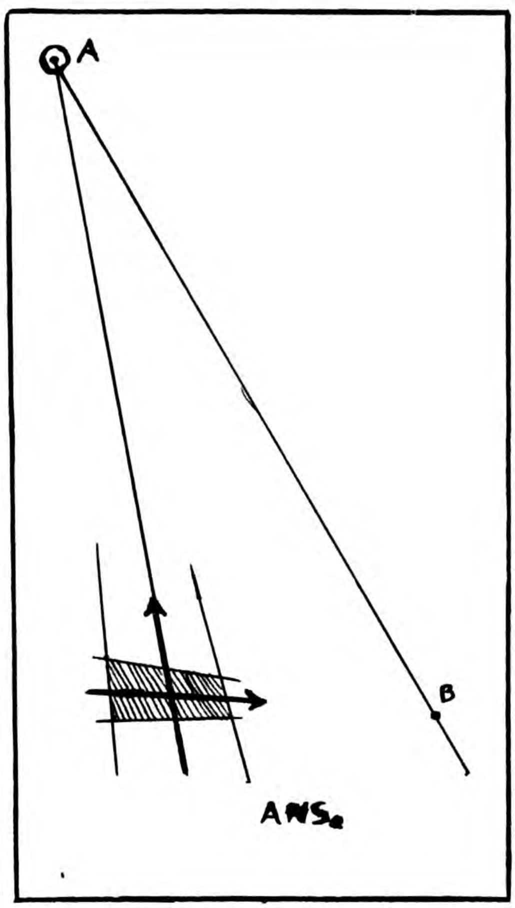
   ANS: Yes. If the magnetic radio bearing (obtained by adding the relative radio bearing to the magnetic heading of the plane) is referred to a magnetic compass rose on the chart, it may be plotted.

2. You are about to establish a radio fix by bearings on two transmitters. One of these transmitters is straight ahead and the other is at right angles to the track. Which bearing should be taken first? Why?

ANS: Take a bearing on the station ahead first. The line of position obtained from this station will run parallel to the track. When this line is advanced to cross with that taken from the second station, it will just have to be stretched. If this first line is made fairly long in the first place, it will not have to be advanced at all.

3. In the diagram below at the left, a navigator has plotted two radio bearings. He believes that the bearing on station "A" could be in error 5° and that the bearing on "B" could be in error 3°. Show the area of possible positions of the plane.





CLASSROOM PROBLEM
(Use H.O. chart #VP-102 or the equivalent.)

You are to make a trip from Baltimore, Md., to Bermuda. The flight forecast has been analyzed and the flight plan indicates that the trip should be made at 7000 ft.

Information for the climb to 7000 ft. is as follows:

Average wind 270°-22 kts.
Average temp. 5° C.
Ind. airspeed 120 kts.
Takeoff time is 1430

Required: True airspeed in the climb ______________

Compass heading during the climb. (Allow 4° E. Dev.) ______________

Groundspeed during climb ______________

At 1500 you pass over radio station NBN and level off at 7000 ft. indicated altitude. The temperature is 0° C. Indicated airspeed is 140 kts.

According to forecast, the wind should be 240°-30 kts.

Required: T.H. and G.S. to Bermuda ______________
C.H. to steer (allow 4° east Deviation ______________
Where do you expect to be at 1530? ______________

At 1535 you receive a QTE of 170° from NFK.

At 1540 you receive a QTE of 064° from NCZ

Required: Plot the running fix
What wind has been acting on the plane since 1500? ______________
1550 position of the plane ______________
C.H. and groundspeed to Bermuda (allow 4° east Dev.) ______________
1600 position of the plane ______________
1630 position of the plane ______________

At 1650 you pass over a ship in Latitude 36°-05' N., Long. 71°-12' W.

Required: Track and G.S. made from 1550 ______________
What average wind has been acting on the plane? ______________
1700 position of the plane ______________
C.H. to Bermuda from 1700 position ______________
Anticipated G.S. ______________
1730 position of the plane ______________

At 1730 you observe 12° left drift. At 1750 the drift is 7-1/2° left and you time the passage of whitecaps between speed lines. The average time of passage is 11.6 seconds. The factor is .2630.

Required: Wind direction and velocity ____________
Track and G.S. from 1750 ____________
1800 position of the plane ____________
C.H. to Bermuda from 1800 position (Dev. 4° E.) ____________
Anticipated G.S. ____________
1830 position of the plane ____________

At 1840 you obtained a QTE of 300° from Bermuda.

Required: 1840 estimated position on line of position ____________
Estimated wind from 1750 ____________
1850 position of the plane ____________
C.H. to Bermuda from 1850 position ____________
Anticipated G.S. ____________
Estimated arrival time (E.T.A.) at Bermuda based on current groundspeed ____________

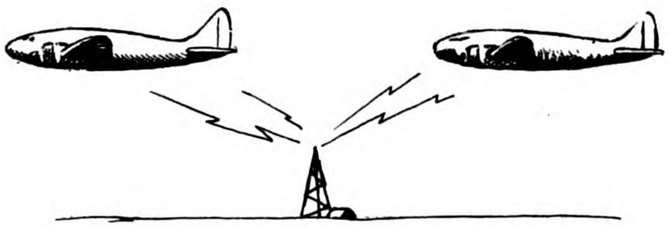
At 1900 you commence to descend and land at Bermuda at 1935.

Required: Total flight time ____________
Total distance covered ____________
Average groundspeed ____________
Average airspeed ____________
Average wind component helping or hindering ____________

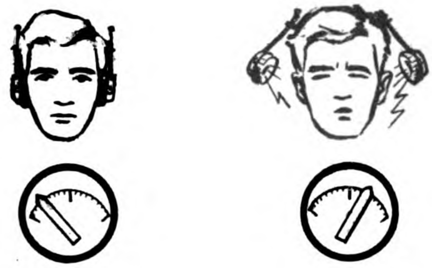
NOTE: The simulated flight problem just given is but one of many that should be given the student at this time. Approximately 40 hours more should be devoted to working just such problems in order to coordinate the knowledge acquired to date.

Under no circumstances should the student take to the air or commence the study of celestial navigation until he has developed speed and accuracy in every phase of this work.

RADIO SIGNAL STRENGTH
(Change with distance and receiver sensitivity)



Weaker Louder
Station Distance



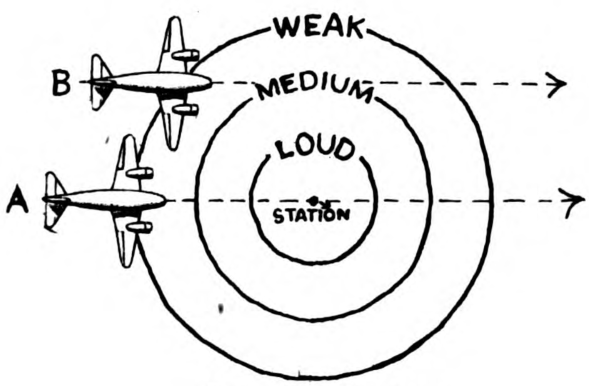
Weak Loud
Receiver Sensitivity

As a plane flies directly toward any radio station, signals become stronger.

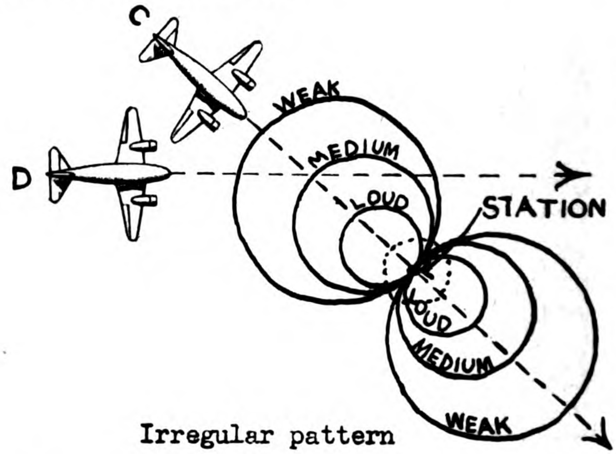
As a plane flies directly away from any radio station, signals become weaker.

When the volume control (or sensitivity control) is advanced, it makes signals stronger. If the volume control is retarded, the signals become weaker.

Most home broadcast receivers have an automatic volume control which keeps the signals fairly constant. The <u>automatic</u> volume control is <u>not</u> employed in receivers used on aircraft for certain purposes to be described.



Circular Pattern



Irregular pattern

At various distances from the station shown above at the left, circles have been drawn showing the relative strength of the signals .

Plane "A", left above, flies toward the station. The signals become louder on approach. After leaving the station, the signals become weaker until they become inaudible. It is assumed that the volume control is not touched during this flight.

Plane "B", left above, flies past the station to one side of it. When the plane is north of the station, the signals will be loudest, but not as loud as if the plane had flown nearer to the station.

The actual distances at which weak, medium and loud signals can be encountered depends entirely upon the actual setting of the volume control and the power of the station. For this reason, no scale of miles is shown on any diagram of this sort.

The right hand figure shows the pattern of a station which transmits principally northwest and southeast.

The plane "C" encounters louder signals as it approaches the station and as it leaves the station behind these die away.

Plane "D" on the other hand is somewhat northwest of the station when it encounters the strongest signal. When the plane passes north of the station the signal strength will have started to decrease.

EXAMPLE PROBLEMS

1. If a plane flies toward a station on a track which passes over it, will signals increase REGARDLESS of the station pattern?

   ANS: Yes. This will generally be true of low frequency stations. Stations at very high frequencies have other peculiarities in transmission which will modify this statement somewhat.

2. If a plane flies past a station, will the signals be greatest when the station is directly to the right or left of the plane?

   ANS: Not necessarily. This depends on the directional transmission pattern and also on the allowance made for wind.

3. What does wind have to do with problem #2?

   ANS: When the transmission pattern is circular, the loudest signals will be heard at a point where the station is at right angles to the track. When the heading differs from the track (as it would if an allowance were made for a cross wind), the station will not be at right angles to the heading when it is at right angles to the track.

CLASSROOM PROBLEMS

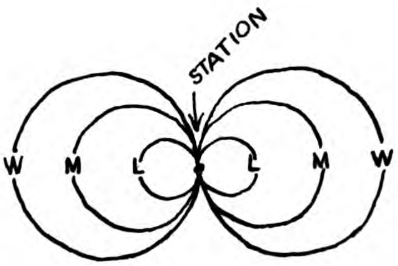
1. How would the signal change if a plane flew a circle around a radio station of circular pattern at any given distance?

   ANS: ______________________________

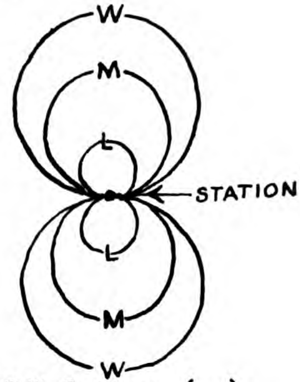
2. Describe the signal in the right hand diagram above at the following bearings from the station to the plane if the plane flies a circle of constant radius around the station. (See small dotted circle in illustration.)

Direction	Signal	Direction	Signal
North	______	South	______
NE	______	SW	______
East	______	West	______
SE	______	NW	______

RADIO RANGE STATIONS



"A" Pattern (•–)



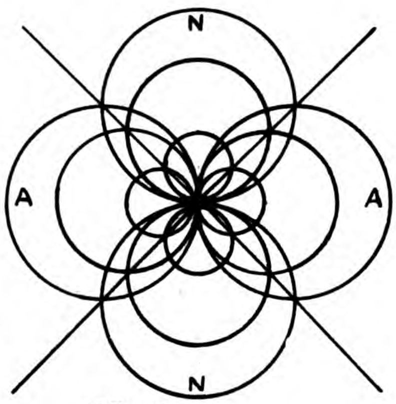
"N" Pattern (–•)

A radio range station transmits two signals, each of which has patterns as shown separately above.

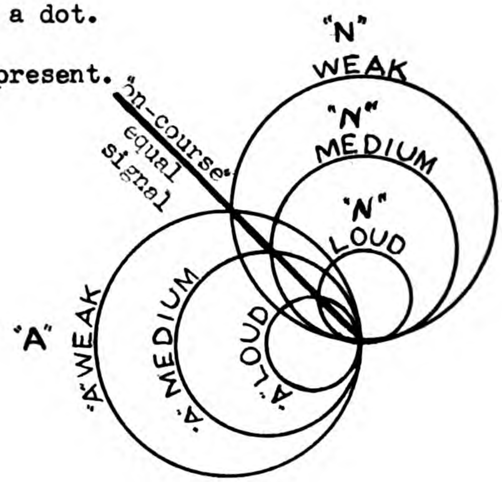
The "A" pattern signal is a dot, space and a dash.

The "N" pattern signal is a dash, space and a dot.

Either the "A" or the "N" signal is always present.



ACTUAL



SIMPLIFIED SECTOR

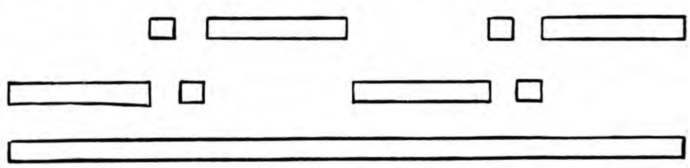
Both "A" and "N" signals are sent from the same radio station. Both patterns are shown at the left. For simplification, only a part of the pattern is sbwn at the right above.

It will be noted, in the right hand diagram, that the "A" and the "N" loud signals intersect at one point. Thus, they are equally loud at that point. The same is true for intersections of the medium and weak signals respectively.

"A" signal

"N" signal

Both at equal strength

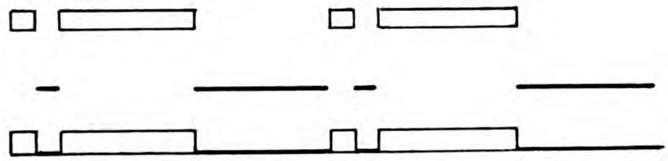


The "A" and "N" interlock as shown above. This means that neither the "A"nor "N" will predominate on the equal signal line.

Strong "A" signal

Weaker "N" signal

Result of hearing both



If the "A" is stronger, it will predominate as shown above. Either "A" or "N" may predominate around a station, depending on the quadrant in which the plane is located.

EXAMPLE PROBLEMS

1. How many on-course signals are there about any radio range?

   ANS: Around the present stations used in the United States, there are normally four. A few two course stations are in use today, and more are expected in the future.

2. Do the four legs (on-course lines) of a radio range always run in the directions shown?

   ANS: No. The four legs may be located in any four directions; furthermore, the legs may be separated by amounts varying from about 30° minimum to about 150° maximum. The sum of the angles between all four legs will always add to 360°.

CLASSROOM PROBLEMS

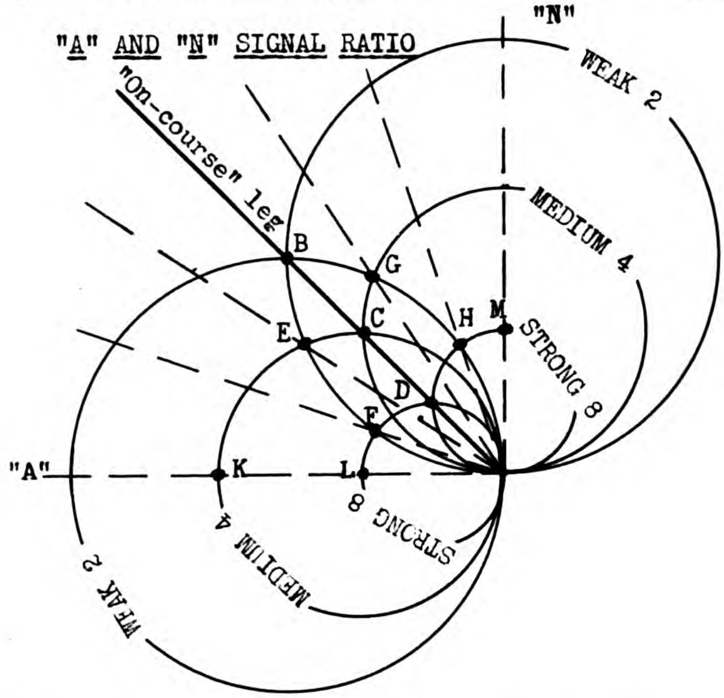
1. What happens to the signal strength as a plane flies toward a station?

   ANS:____

2. Does the Volume control have any effect upon the ratio of "A" to "N" signals?

   ANS:____

"A" AND "N" SIGNAL RATIO



Relative signal strengths have been shown by number in the diagram above. The signal RATIO can be shown by comparing these numbers at any of the locations lettered on the diagram.

Point	"A" Strength	"N" Strength	Ratio	Predominating Signal
B	2	2	1	On-course
C	4	4	1	On-course
D	8	8	1	On-course
E	4	2	2	"A"
F	8	2	4	"A" (greatly)
G	2	4	2	"N"
H	2	8	4	"N" (greatly)
K	4	0	HIGH	"A" only
L	8	0	HIGH	"A" only
M	8	0	HIGH	"N" only

Not only will the ratios hold true at the points shown but these same ratios will hold true at any point on the dotted line passing through the point.

Thus, the ratio of signals heard depends entirely on the angle between the on-course leg and a line out to the plane's position.

EXAMPLE PROBLEMS

1. What would happen if the plane flew away from the station along the dotted line passing through "F"?

   ANS: The "A" signal would greatly predominate and maintain this constant ratio of "A" compared with "N". The TOTAL signal level decreases as the plane leaves the station.

2. If a device were perfected to show the exact ratio of "A" to "N", could this be used to fly the plane into the station along any desired radial line from the station?

   ANS: Yes. Such a device exists although the actual signals sent out from the station are not "A" and "N".

CLASSROOM PROBLEMS

1. A certain ratio of "A" to "N" signal requires the plane to fly a radial of 300° measured from the station. The station has four legs which are NE, SE, SW and NW. What other three radials will give exactly the same signal ratio with "A" predominating?

   ANS:____

2. Suppose in problem 1 that the same ratio were maintained but with the "N" signal predominating. What are the four radials measured outward from the station?

   ANS:____

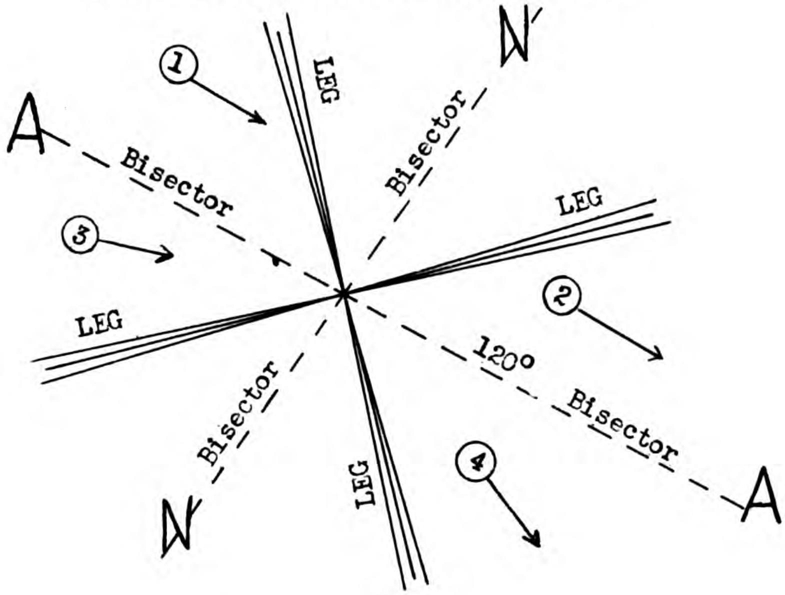
3. What would happen to the total signal in the two cases above if the plane were flying away from the station in both cases on the radials named?

   ANS:____

4. Would the plane pass directly over the station in flying the above radials toward the station and maintaining the ratio determined?

   ANS:____

RADIO RANGE ORIENTATION
(Finding relation of plane to station)



Orientation is the process of determining the position of a plane with relation to a range station.

Two basic steps will solve the problem:

STEP 1. Head the plane (roughly) parallel to the bisector of the quadrant whose letter predominates ("A" in this case, whose bisector is about 120°).

STEP 2. Listen to the signal:

1. The total signal may get louder or weaker.
2. The "A" may become more or less predominant
(Follow the indication above which is changing most rapidly.)

In the diagram above, the navigator hears an "A" signal which predominates over the "N" signal in fairly high ratio.

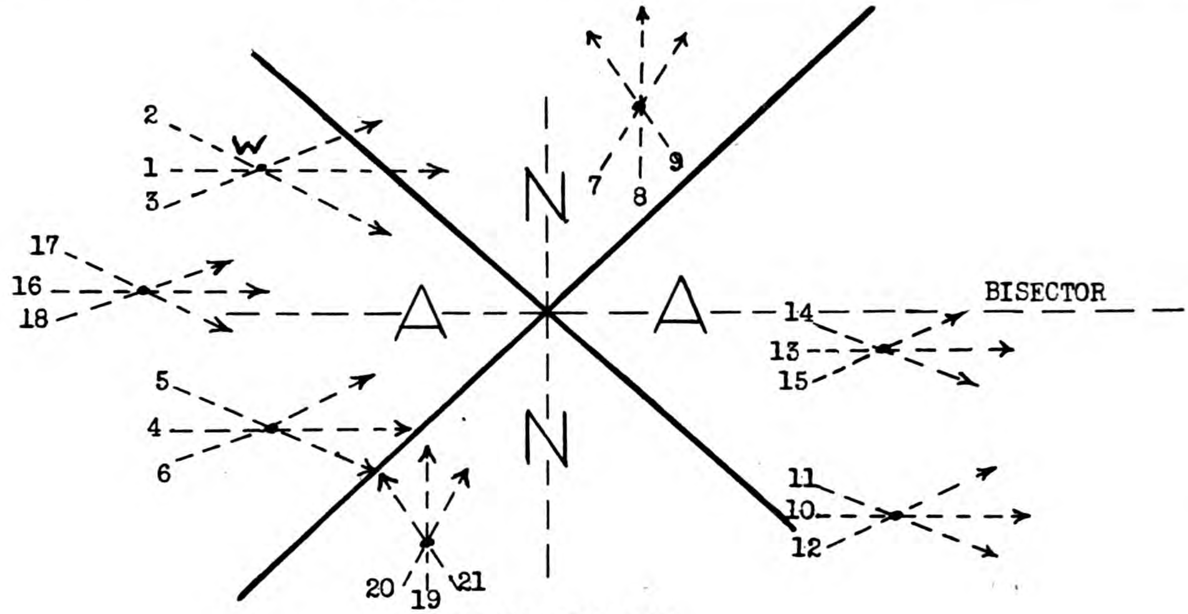
There are only four general locations at which the plane can be located as shown at points 1, 2, 3 and 4.

Case	Change Heard	Wind	Conclusion Reached
1	"A" less prominent	None	A leg is being approached. This must be either the north or west leg. The plane is in the NW "A" sector headed into the quadrant.
2	"A" more prominent	None	The plane is leaving a leg and going out into the quadrant. Either the east or south leg is being left behind. The plane must be in the SE quadrant, headed away from the station.

Case	Change Heard	Wind	Conclusion Reached
3	Signals stronger	South	No perceptable change in ratio is noted but the whole signal is increasing. The plane is approaching the station. The plane must be in the NW quadrant and only at 3.
4	Signals weaker	North	No perceptable change in ratio is noticed but the whole signal is decreasing. The plane is leaving the station. This could only happen on southeasterly heading in the SE "A" quadrant at 4.

Combinations of conditions 1 and 2 with 3 and 4 may exist. The most noticeable change should govern.

In any of the cases above, the heading of the plane may be altered to fly to one of the radio range legs. It makes no difference what plan is being followed by the pilot. If the navigator listens to the change of signals, he can determine for himself what is happening quite readily. It is especially important to keep good volume in the headphones. It is just as important to leave the volume control alone until the signal finally gets too strong or too weak. It can then be adjusted so as to give good volume again.



EXAMPLE PROBLEMS

1. The plane is at "W" in the diagram above. Cases 1, 2 and 3 show the possible tracks with no wind, a north wind and a south wind <u>when the heading of the bisector is flown</u>. What conclusions would you draw in each case?

ANS:

Number	Change Predicted	Wind	Conclusion
1	"A" less prominent	No wind	Plane approaching leg. Must be west "A" quadrant.
2	Total signal louder	North	Plane approaching station. Must be west "A" quadrant.
3	"A" less prominent rapidly	South	Plane approaching leg. Must be west "A" quadrant.

No assumption as to the leg to be intersected may yet be made for the plane might cross the SW leg with a very strong north wind coupled with inaccuracy in heading or wrong information about the range (ranges are changed at intervals to suit new airway conditions).

CLASSROOM PROBLEMS

1. Make a table like the one above for the conditions roughly represented at points 4 to 21 inclusive.

ANS:

Number	Change Predicted	Wind	Conclusion
4	______________	____	______________________
5	______________	____	______________________
6	______________	____	______________________
7	______________	____	______________________
8	______________	____	______________________
9	______________	____	______________________
10	______________	____	______________________
11	______________	____	______________________
12	______________	____	______________________
13	______________	____	______________________
14	______________	____	______________________
15	______________	____	______________________

Number	Change Predicted	Wind	Conclusion
16	____________	______	____________________ ____________________
17	____________	______	____________________ ____________________
18	____________	______	____________________ ____________________
19	____________	______	____________________ ____________________
20	____________	______	____________________ ____________________
21	____________	______	____________________ ____________________

2. You will realize that you have been predicting what would happen to signals with a map before you. In practice you will only hear the signals and will have to interpret from them what is happening. A radio range has its legs at 30°, 110°, 240° and 340° magnetic. One "N" quadrant is between the 340° and the 30° leg. In this case all legs are measured AWAY FROM THE STATION. (In practice the range legs may be given in the following form in data supplied to the navigator: N-210-A-290-N-60-A-160. In this case the legs are given INTO THE STATION. The proper quadrant letter is shown between each leg.) Draw a diagram of this range and give your conclusions in each of the cases below. Plot the approximate flight path followed in this case.

Signal Change in Five Minute Period	Conclusion
(a) Heading 270° magnetic. No change in total signal. "N" continues to predominate strongly.	
(b) Heading 270° magnetic a few minutes after problem (a) above. Total signal about same. "N" is somewhat less prominent.	
(c) Plane has now turned to 5° magnetic. Total signal is becoming weaker, "N" is becoming more prominent.	
(d) Plane turns 180° to magnetic heading of 170°. Total signal increases. "N" is very prominent.	
(e) The navigator takes off the headphones for a few minutes. The heading is maintained at 170°. Upon placing the headphones on his head again he hears a prominent "N" but the total signal is decreasing.	
(f) Where is the station in relation to the plane now?	

3. A plane approaches a newly commissioned range station. No data regarding the direction of the legs is available. Having plenty of time at his disposal, the navigator decides to plot the legs roughly from signals he hears.

The plane is flying on instruments with a wind of about north-50 MPH, and the airspeed is 200 MPH. Plot the range from the information given below.

The plane is headed true west at 1240 GCT. A strong "N" signal is heard. Ten minutes later the "N" becomes less prominent and the plane heads south. At 1300, the plane crosses a leg and goes into an "A" quadrant.

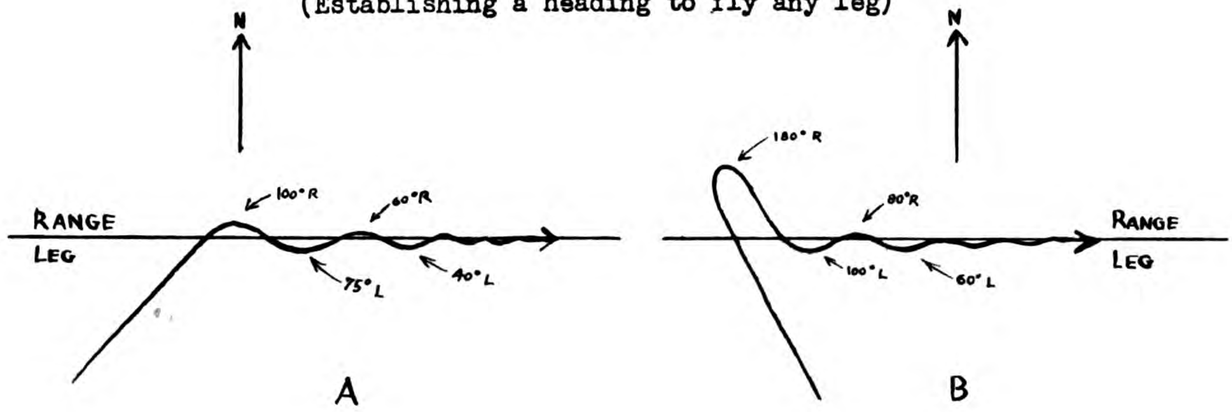
At 1310, the plane again crosses a leg and goes into an "N" quadrant. The plane is headed east at this time.

The "N" signal becomes prominent fairly rapidly now and the total signal increases somewhat. A sudden break in the clouds gives the navigator a view of a town which is 40 miles directly south of the range station at 1330.

At 1350, the plane turns north. The "N" signal becomes less prominent slowly and the total signal level changes slightly.

At 1405, the plane crosses into an "A" quadrant. The "A" becomes more prominent rapidly and finally a full "A" is heard. Very soon the "A" becomes less prominent and a leg is crossed at 1420.

BRACKETING
(Establishing a heading to fly any leg)



When a plane intersects a radio range leg, it is not immediately possible to head the plane along the leg unless the wind and exact range leg direction are known.

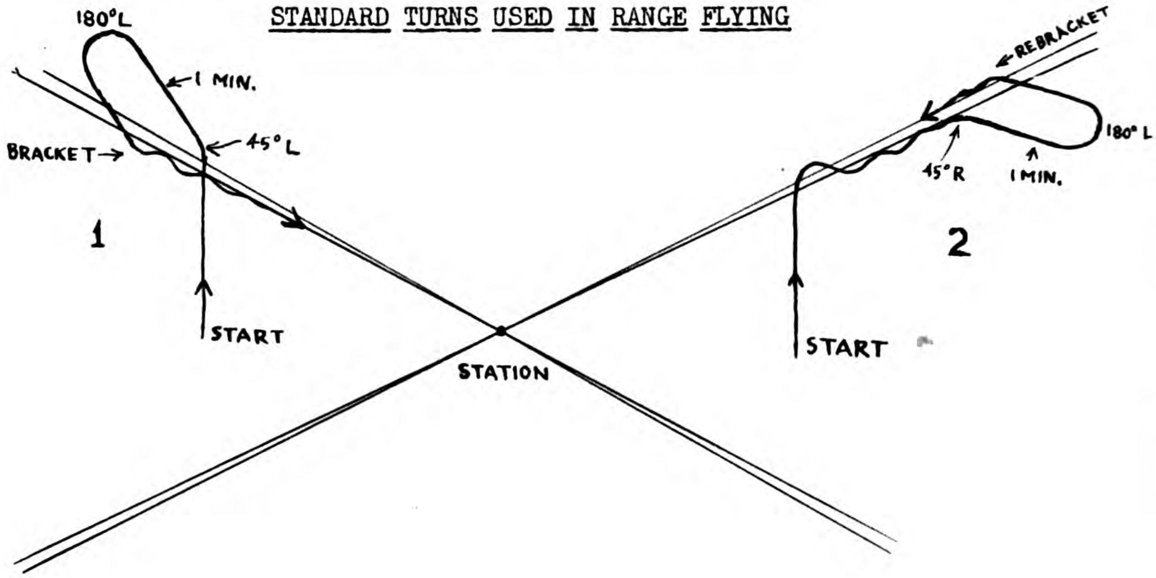
When either of these two factors are unknown, the pilot uses the bracketing system shown above to keep on the leg.

The bracketing method shown above is used to determine the heading necessary to keep on any leg that happens to be intercepted. Wind and the direction of the leg need not be known.

Upon passing through the leg and receiving the other quadrant signal, the plane is placed in a right turn. This turn is continued until either (a) the plane again intersects the leg or (b) until a 180° turn has been made in which case the turn is stopped.

As soon as the plane is again back in its original quadrant, a left turn of about 150° is made until the leg is intercepted again. The plane then turns right about 80° or until the quadrant signal is heard. By successively reducing the amount of right and left turn, the plane's track will be aligned with the range leg. If a turn fails to produce the expected change in signal, this definitely establishes a direction inside of which the leg must exist.

STANDARD TURNS USED IN RANGE FLYING



After the orientation problem has been solved, the pilot will go to a specific leg as soon as possible. Two procedures are possible after crossing a leg.

1. Having crossed through the leg, the heading is altered 45° away from the leg. This heading is maintained for a period of about one minute in order to insure sufficient distance between plane and station to perform the bracketing procedure.

   At the end of this time, a 180° turn is made toward the leg. When the leg is intercepted, the pilot will commence bracketing toward the station.

2. Another case is shown at the right. Here the pilot actually bracketed the leg (outgoing) before making a standard turn which is shown. Three things will definitely be established (a) the decrease in signal will positively establish the fact the plane is leaving the station; (b) the approximate drift can be determined, giving the pilot an idea of the magnitude of the cross wind; and (c) the pilot will be assured of having sufficient time to fully bracket the leg on the incoming heading. If there is a cross wind, the incoming heading will not be the reciprocal of the outgoing heading.

EXAMPLE PROBLEMS

1. Why doesn't the pilot turn more than 180° as the last step in standard turn #2 above?

   ANS: As he may have considerable wind from the north, a turn of more than 180° might cause him to miss the range leg as he drifts south during the turn.

2. During one part of a bracketing problem, the plane turns right 30° so as to leave the leg. The on-course signal continues to be heard for some time however. What should be done?

ANS: Evidently, this heading is about the same as the heading necessary to fly the leg. The thing to do is to turn about 10 to 20° more to the right so as to establish the edge of the on-course. Upon finally coming out into the quadrant a little, the next turn need be only about 25° left at the most.

CLASSROOM PROBLEMS

1. A leg whose published direction was 45° magnetic from the station was bracketed. It required a heading of 60° magnetic to fly it. What approximate heading would be necessary to fly into the station?

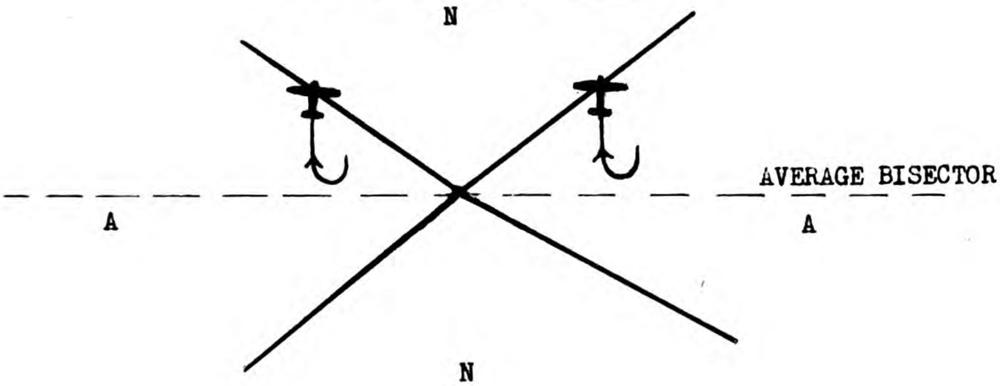
ANS:________________________________

2. The radio range is a useful device for determining drift. Explain how you would use it to determine drift angle. Does this enable you to determine the wind direction?

ANS:________________________________

____

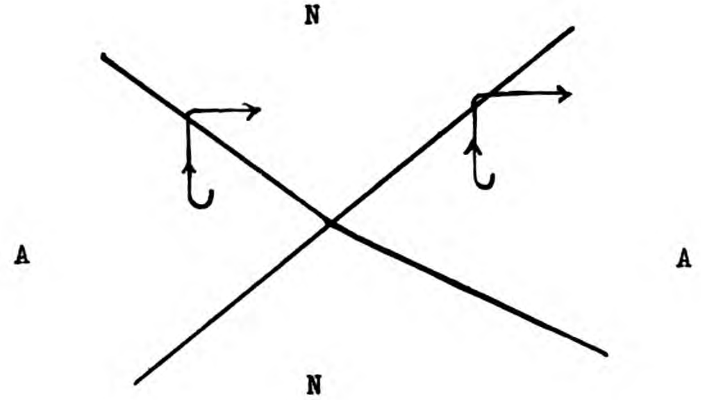
<u>90° ORIENTATION SYSTEM</u>



This system of orientation is based on a complete reversal of signal rather than a change of signal ratio or change of signal strength.

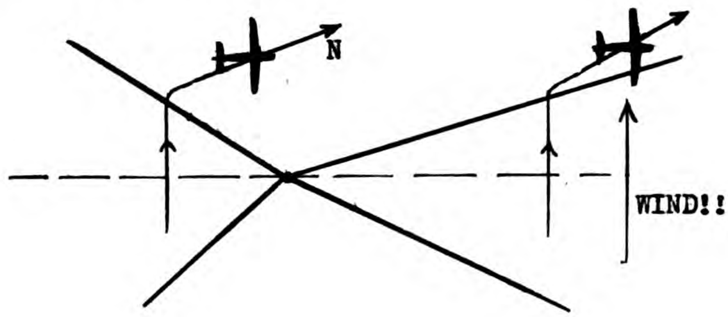
The <u>average bisector</u> of the two possible quadrants in which the plane must be located is first determined and a heading at right angles to this average bisector is flown. See the diagram above. If, while on this heading, the signal becomes a more pure "A" or "N" (indicating entry to the mid-quadrant area), the heading should be reversed so as to approach the nearest leg.

Notice in the diagram above that either the northwest or northeast leg will be intercepted.



As soon as the leg is crossed, turn 90° right. This new heading will either bring the plane into the "N" quadrant or back into the "A" quadrant, depending on whether the northwest or northeast leg has been intercepted as above. If the northwest leg has been crossed, the pilot will hear an "N"; if the northeast leg has been crossed, an "A" will be heard soon.

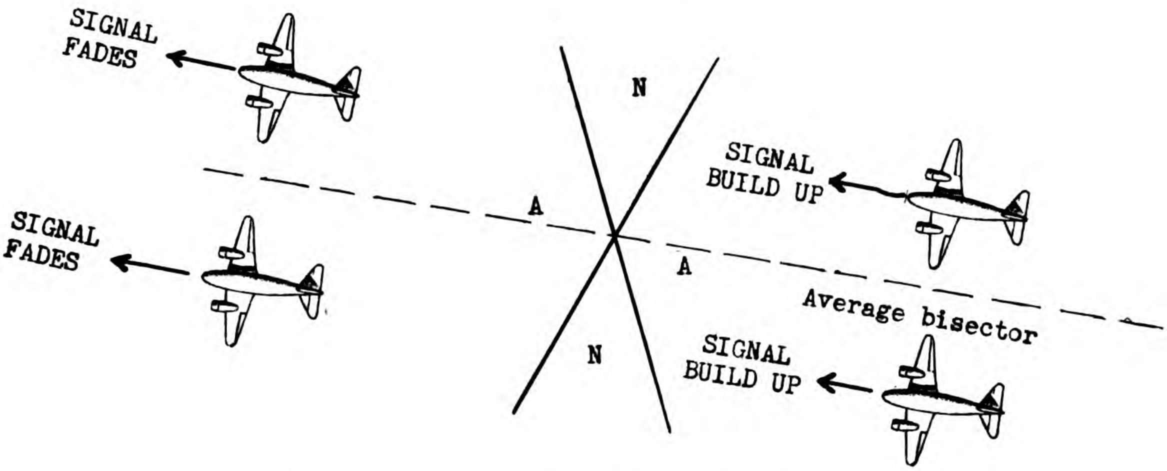
After the leg has been identified, a left turn may be made to pick up the leg and the bracketing procedure commenced.



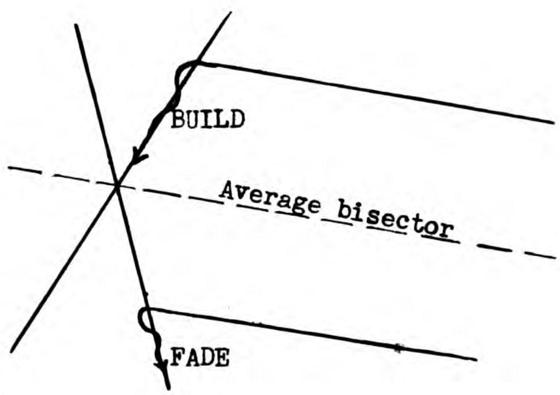
Note the weakness of this method as shown above. A high wind which, in this case, is from the south may result in "identifying" the wrong leg! Notice how, at the upper right, the plane has failed to come back into the "A" quadrant after making the usual 90° turn.

In this method of orientation, stress is placed on change of signal. In the system discussed previously, stress was also placed on change in signal intensity. For this reason, it serves for all radio range systems and wind conditions and is, therefore, to be preferred.

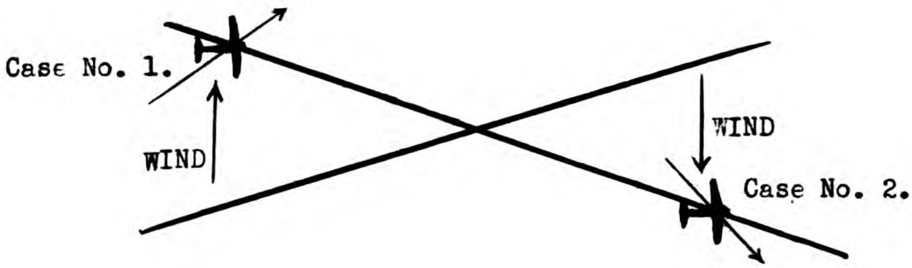
PARALLEL SYSTEM OF ORIENTATION



In this system of orientation, the pilot heads the plane parallel to the average bisector of the quadrants whose letter he hears. An increasing signal indicates an approach to the range station. A decrease in signal intensity indicates a departure from the station. In either case, identification of the quadrant is achieved.



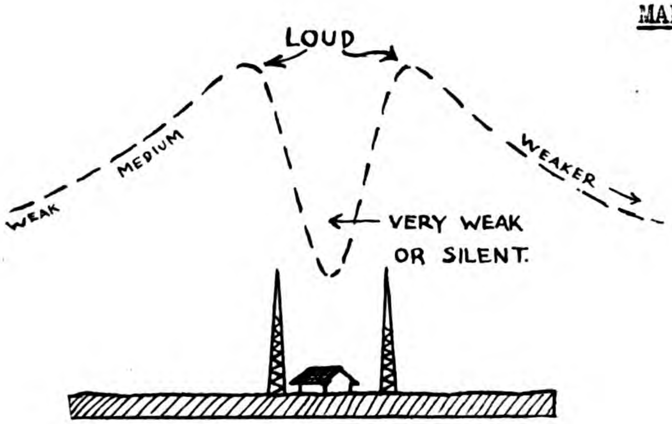
After quadrant identification, the plane is headed toward the station on a heading parallel to the average bisector until a leg is intercepted. The leg is then bracketed. Bracketing in some cases is not enough to identify the leg and final identification is achieved by again listening for a fade or build in signal strength.

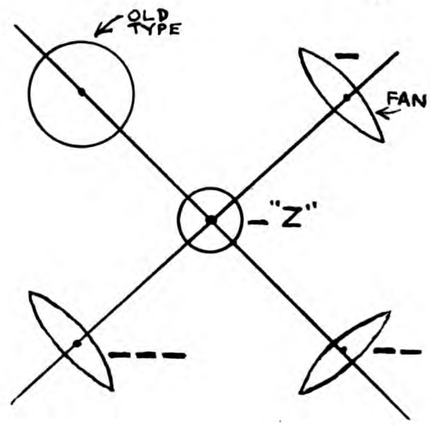


The effect of wind is shown in the two cases above. In case #1, this results in intercepting a leg with no appreciable change of signal strength. In case #2, a leg is crossed though the total signal decreases.

Stress in this method of orientation is placed on a fade or build up in general signal strength. The system set forth at the beginning of this discussion stressed signal ratio as well. Because of this, it serves for all radio range systems and wind conditions and is, therefore, to be preferred.

MARKERS





Changes in signal intensity resulting from flying over a radio range station are shown graphically above at the left. If the volume control is left undisturbed, the signal level builds up rapidly as the plane gets close to the station.

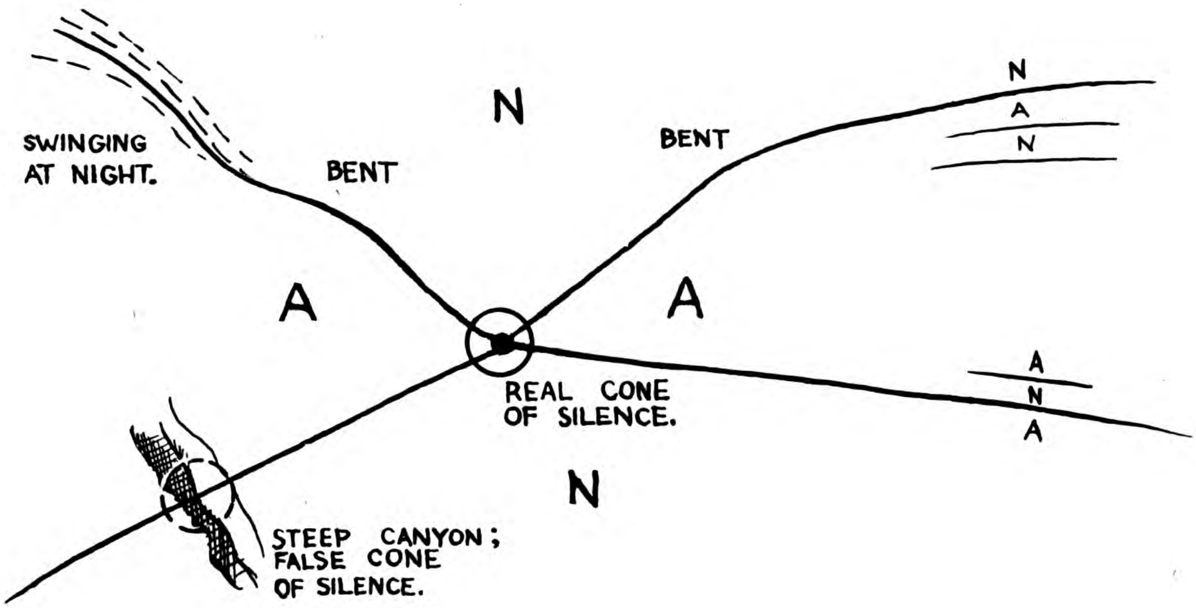
Radio signals are radiated poorly upward from vertical radiators. For this reason, there is very little or no signal immediately above the range station itself. The area in which little or no signal is heard is shaped somewhat like an inverted cone - hence the name "cone of silence". Passage of the plane through this cone is an indication that the plane has passed over the range station.

Some radio range stations do not have vertical towers. In this case, the cone of silence depends on the fact that the airplane antenna is vertical in its behavior. Thus, when the plane flies over the station, it will give the cone of silence itself as the airplane antenna area directed toward the radio station is small with the plane over the station.

A second and very high frequency transmitter has been added at most radio range stations which sends a STRONG SIGNAL upward into the cone of silence. This signal is received aboard aircraft and lights a lamp on the instrument board further confirming the fact that the plane is over a station. In addition, there is a high pitched squeal in the headphones, telling the pilot that the signal lighting the lamp is the correct one. This type of marker is called a "Z" marker.

In addition to the "Z" marker, another type of marker is used on certain legs of many radio ranges. It projects a fat fan of signal upward. It lights the same lamp as used for the "Z" marker, but the signal is coded in dashes. One dash is used for the first leg measured from magnetic north, two dashes (repeated frequently) on the next leg clockwise, three for the third and four for the fourth leg. The high pitched tone and the light both show the dash signals.

FALSE INDICATIONS FROM RADIO RANGES



When a radio range crosses rough country, especially where it passes over a steep canyon, there may be false cones of silence. The signal decreases, possibly to silence, and then comes back to the original level. The signal strength just before a real cone INCREASES GREATLY, drops to silence, INCREASES to a loud signal and then quickly dies down as the station is left behind. These four things should be clearly heard at a real cone of silence but will not be heard at a false cone of silence.

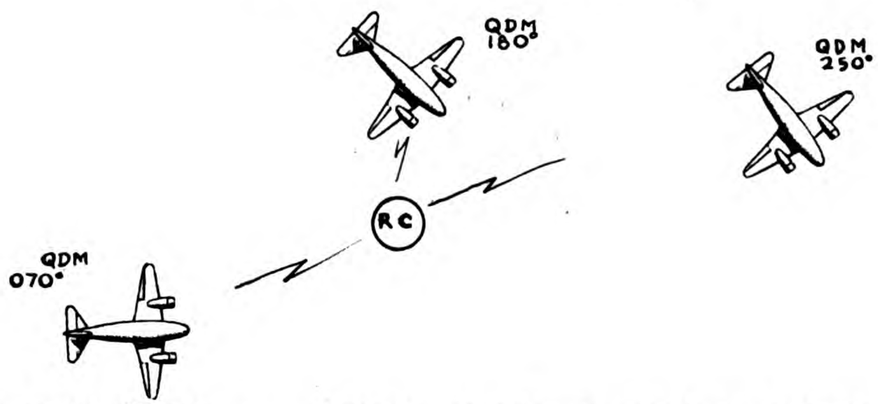
Radio range legs sometimes swing at night. The leg will wander back and forth over a rather limited angle and will be hard to follow accurately. This is illustrated in the upper left.

Radio range legs sometimes bend rather sharply as they pass over certain objects on the ground such as hills, rivers, railroads, etc. These bends are annoying to the pilot but proper continuation of the bracketing process will again establish the heading to fly the remainder of the leg. Where it is known that a bend exists like the one on the NW leg of the range above, the pilot maintains his

heading as he knows he will be back on the leg soon. If there is but one bend, the heading must be altered.

Another phenomenon is the so-called multiple. It is illustrated on the two easterly legs above. Actually, a multiple is much like the true leg. Often it will have reversed letters from the normal leg. Occasionally, it will be arranged just like the true leg as shown by the lower multiple on the NE leg above. There is no harm in bracketing and flying multiples as they generally lead toward the station. Of course sufficient altitude must be maintained to clear all objects either side of the main radio range leg. Multiples only exist some 10° at the most to the right and left of the leg. In flying off the end of a multiple, the pilot should make the proper correction to get back on the true leg. Unless the multiple is a reversed type (not common), this merely calls for the same kind of correction he would make if he suddenly found a bend in the leg.

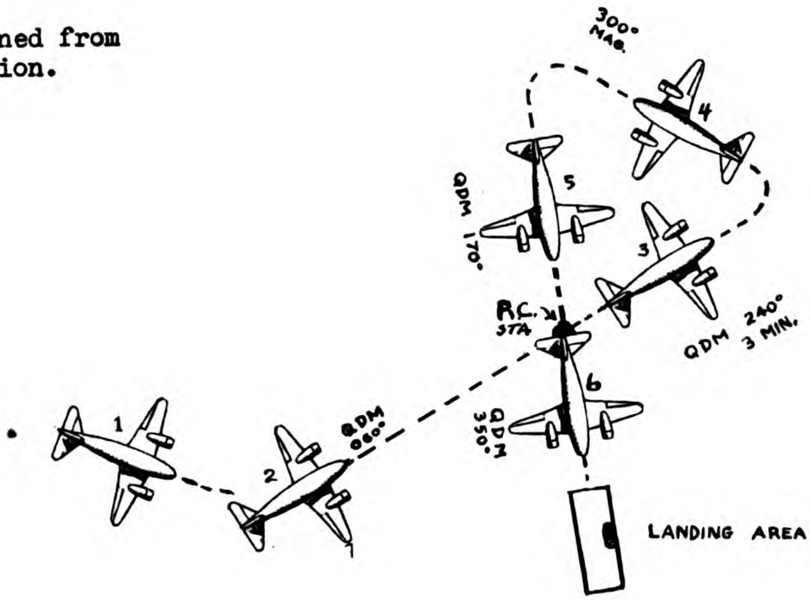
QDM APPROACHES - CASE 1



The term QDM means: "Steer.......degrees magnetic to reach me with no wind." The planes in the illustration above are in the vicinity of a radio-compass station and each would receive (on request) the QDM written adjacent to it. The station could be reached by heading in the QDM direction and making allowance (by trial and error) for the wind.

CASE 1.

QDM's obtained from ground station.



QDM's are used by the pilot in conjunction with timed runs in order to follow a pre-arranged flight pattern during an instrument approach and let-down at a non-directional station. In the illustration above, a plane is shown making such an approach.

At position 1, the pilot received QDM's of about 075°. The initial approach was to be made on QDM 060° so the plane continued on until QDM 060° was furnished, at which time it was headed toward the station (as in 2 above).

A gradual let-down was commenced after the plane passed over the station. The run was continued on the heading maintained during the initial approach. Note the reversal of the QDM in 3 above.

At 4, the plane is shown maintaining a magnetic heading of 300°. This heading will be maintained until the radio-compass station furnishes a QDM of about 170°.

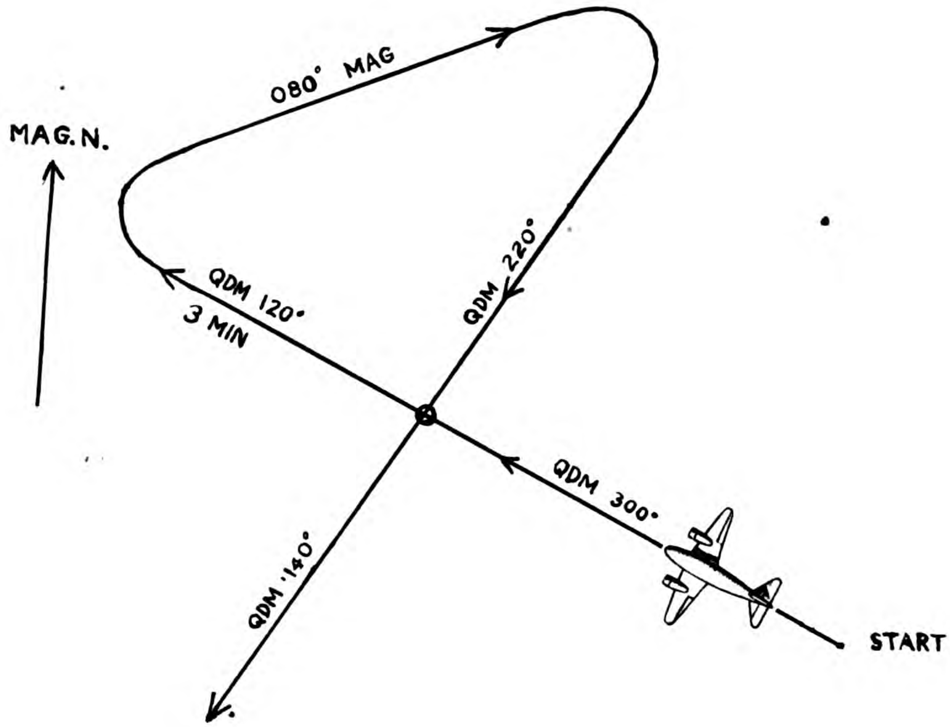
After the final turn toward the station, the QDM of 170° will be maintained (plus or minus allowance for wind) until the second "over" is established.

At this point, the plane should be low enough to let-down to the landing area. Note the reversal of the QDM again at point 6.

QDM APPROACHES - CASE 2

CASE 2.

QDM's determined on plane.



Since a QDM takes the plane to the station, it is a magnetic bearing of that station from the plane.

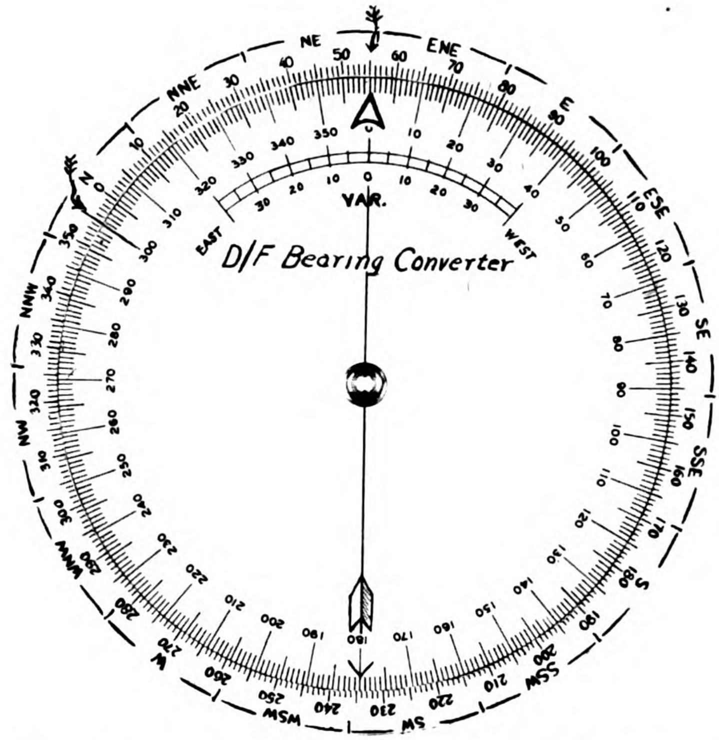
Such bearings, the equivalent of QDM's are often determined by the navigator and radio operator. The radio operator uses the plane's loop antenna and obtains the bearing of the transmitter relative to the plane's head.

The navigator adds this angle to the magnetic heading and thus obtains the magnetic bearing of the station. This information is given the captain of the plane who uses it in precisely the same manner as he would use QDM's supplied by the station itself.

No QDM's are determined when the plane is making a turn because of the difficulty of obtaining either an accurate relative bearing or an accurate compass reading.

In practice, the navigator usually reads the gyro-compass which is kept set to indicate magnetic headings. QDM's are furnished about every 20 seconds throughout the approach.

QDM CONVERTER

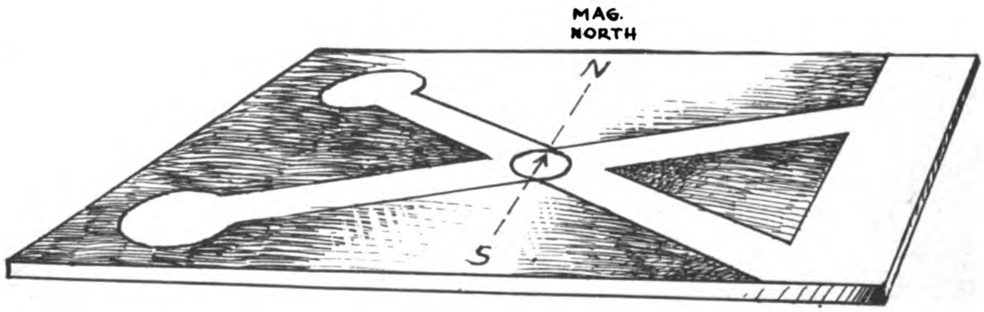


The actual addition of the relative bearing and the magnetic heading is usually performed with a QDM converter such as that shown above.

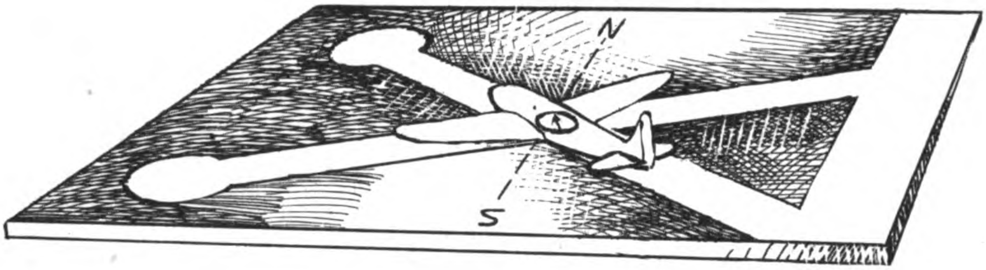
The inner compass rose "A" is rotated until the arrow points to the magnetic heading of the plane on the outer rose. In the illustration, the arrow points to a magnetic heading of 055°.

If a relative bearing such as 300° is received from the radio operator, this 300° is located on the inner rose and the QDM is found opposite on the outer rose. In this case, the QDM to repeat to the captain would be 355°.

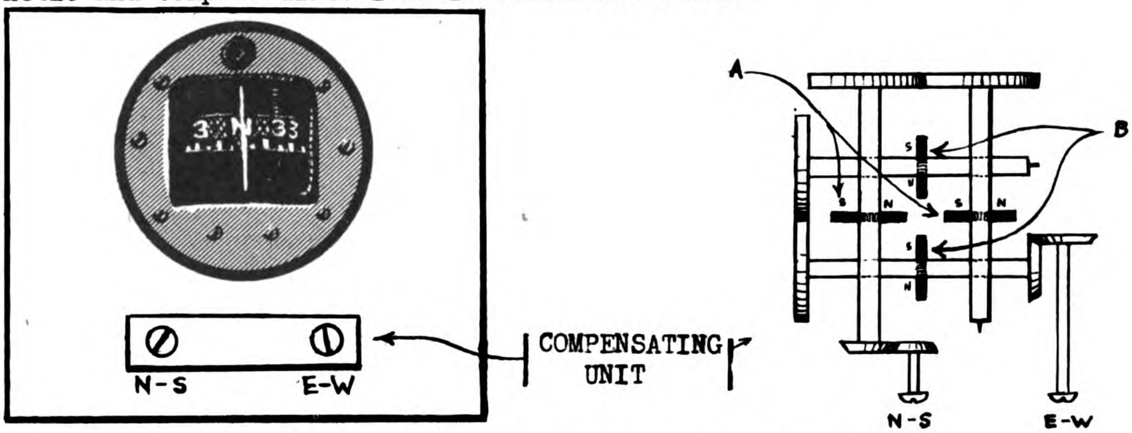
COMPASS COMPENSATION



A compass will point out correct magnetic directions when uninfluenced by local magnetic fields. A compass in the middle of a large airport is a good example of this.

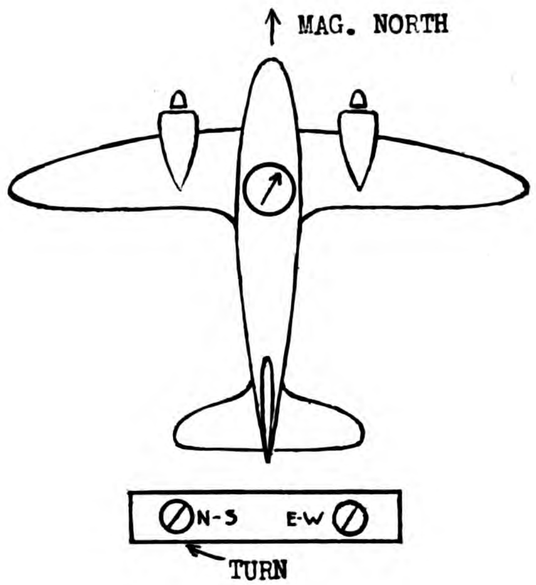


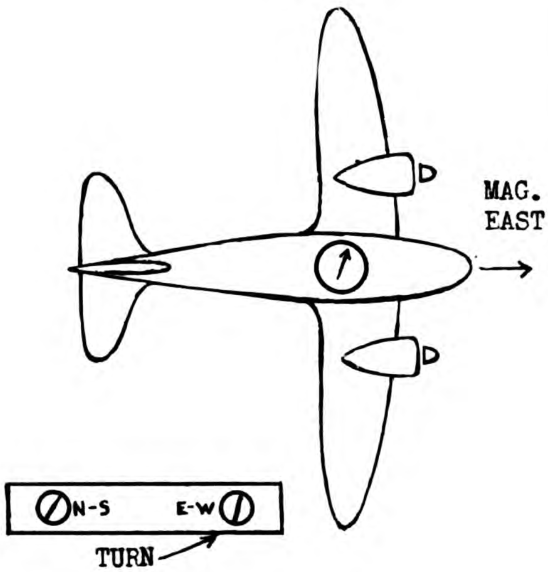
Compasses mounted in aircraft are effected by magnetic fields in the plane and do not, as a rule, point correct magnetic directions. The difference between magnetic and compass directions is called deviation.



Compass deviation may be reduced by creating magnetic fields near the compass that oppose those acting on the compass. This is done by means of a compensating mechanism such as that shown above left, and the procedure is called <u>compensation</u>.

The compensating unit right above, consists of small permanent magnets "A" and "B" mounted in such a manner that, by means of screws N-S and E-W, almost any magnetic field can be built up around the compass.



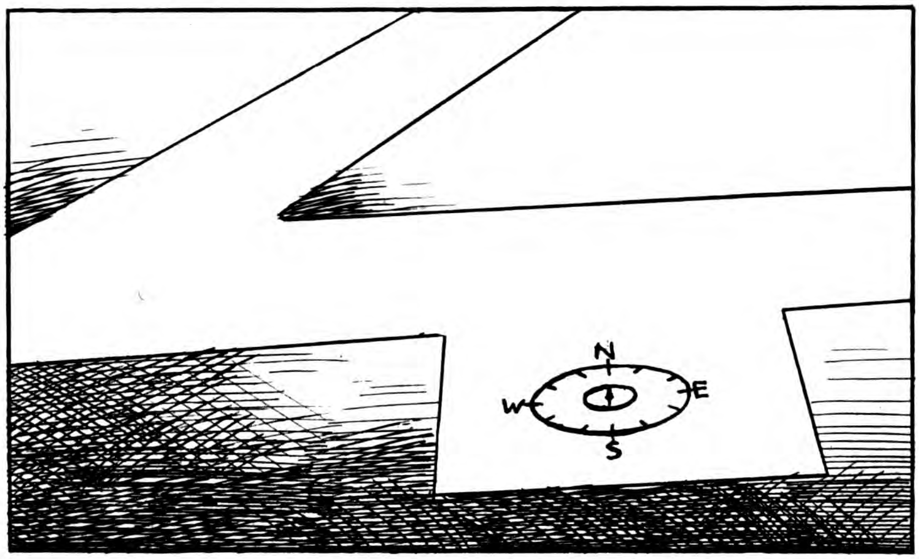


When heading magnetic north or magnetic south, all of the deviation is produced by disturbing forces acting at right angles to the plane's axis. By turning the N-S compensating screw above, all of the effect of this force can be neutralized.

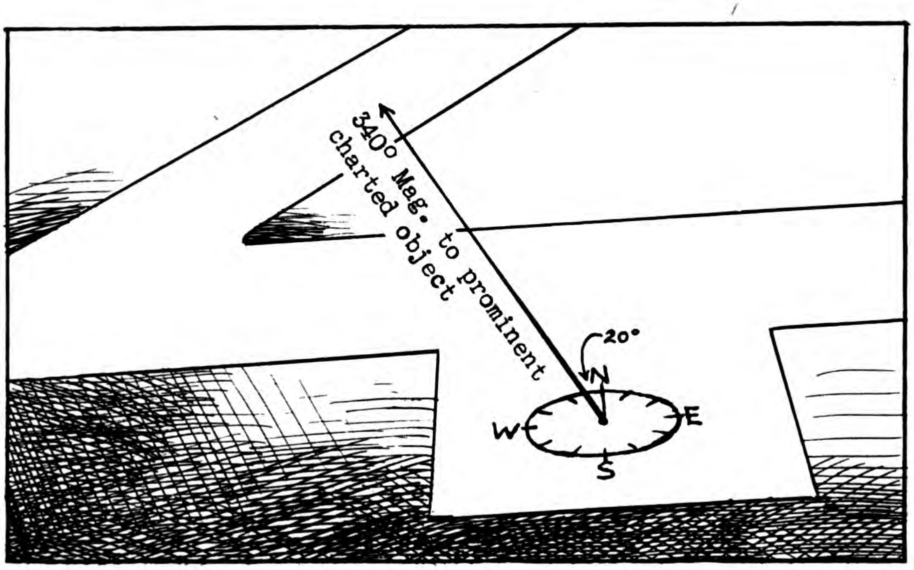
When heading magnetic east or magnetic west, all the deviation is produced by disturbing forces acting in the line of the plane's axis. By turning the E-W compensating screw shown above, the effect of this force can be neutralized.

Neutralization of these two forces is usually sufficient to eliminate or greatly reduce deviations on all other headings.

For this reason, the actual compenstion of aircraft compasses is performed when the plane is headed magnetic north (or south) and when headed magnetic east (or west).

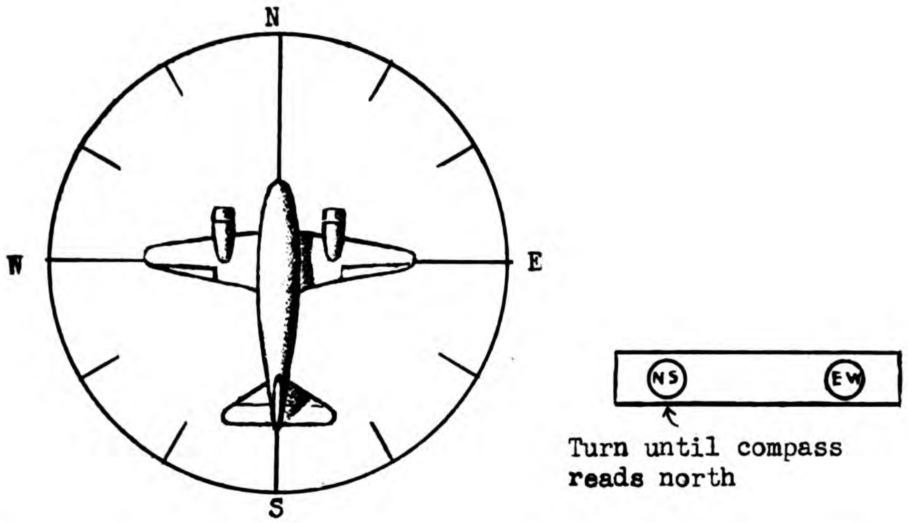


Construct a large magnetic compass rose on the airport ramp well away from any buildings. A good magnetic compass and a long string (or preferably a surveyor's transit) may be used for this purpose.



If no transit or compass is available, obtain the true bearing of some distant and prominent landmark from the chart of the area. Apply the variation for the locality and obtain the magnetic bearing of the object.

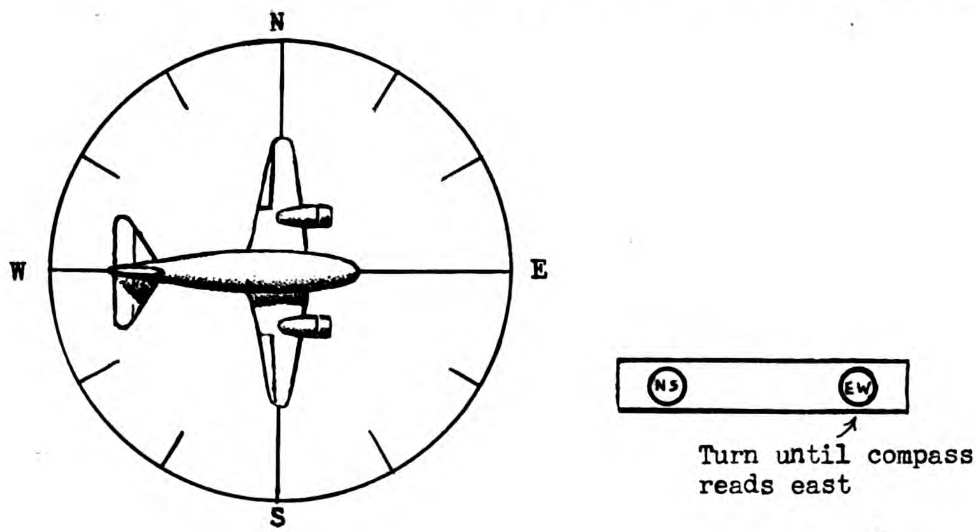
If this magnetic bearing is 340° for example, magnetic north would be 20° right, etc.



Put the plane in the center of the rose and head it magnetic north. Plumb bobs may be used to advantage in heading the plane exactly as desired.

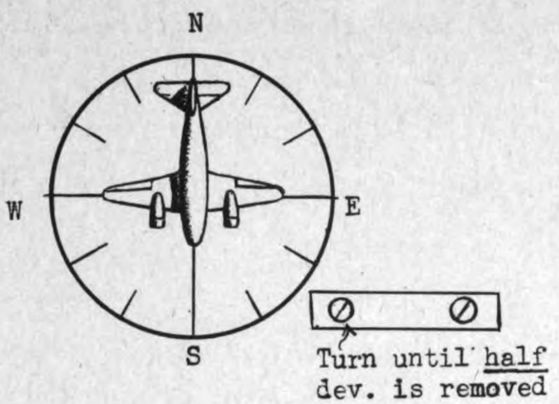
Secure all loose equipment, remove all tools, etc., block the tail up in flying position, if practical to do so. The object of these preparations is to duplicate actual flight conditions as much as possible. Turn on electrical equipment normally operating in flight.

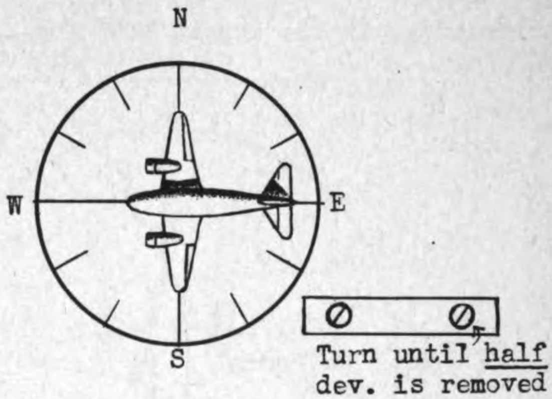
Rotate the N-S compensating screw slowly with a non-magnetic screw-driver until the compass reads north. Tap compass lightly with finger to keep it active.



Change the heading of the plane to magnetic east. Turn the E-W compensating screw slowly until the compass reads east.

Theoretically, this completes the compensation. In practice, however, some deviation may still exist. Continue as follows:

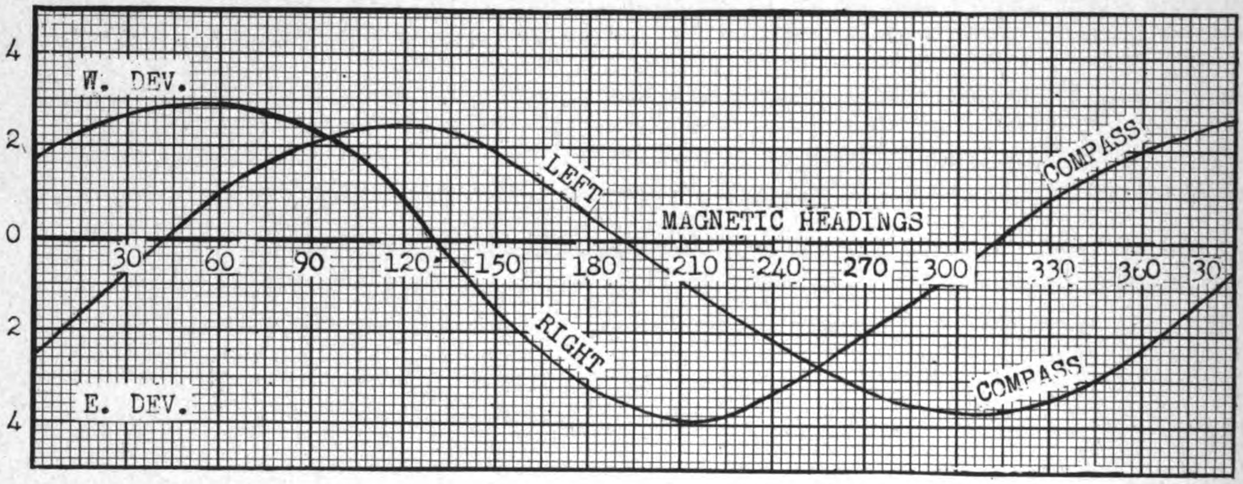




Head the plane magnetic south. Turn the N-S compensating screw until <u>half</u> the deviation (if any) on south is removed.

Head the plane magnetic west. Turn the E-W compensating screw until <u>half</u> the deviation (if any) on west is removed.

This completes the compensation.



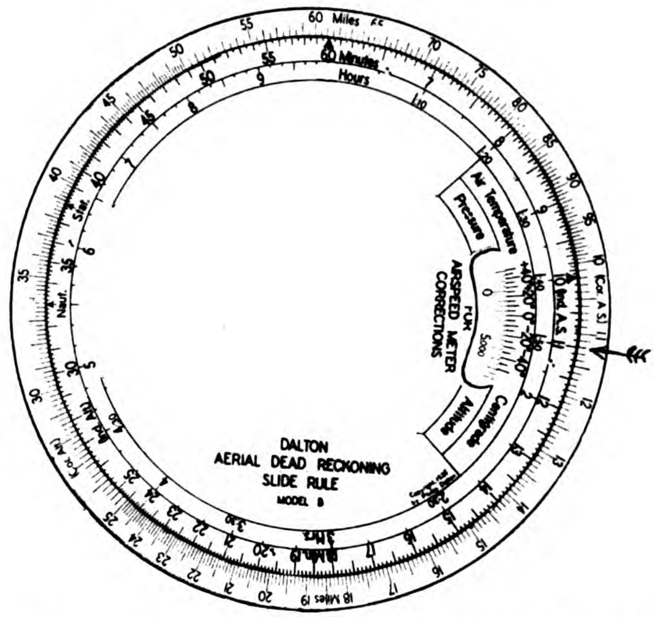
Though the deviations should now be very small, they should be determined and recorded for use by pilot and navigator. Head the plane magnetic north, 020°, 040°, 060°, etc., and record the deviation on each heading. Plot this information on a graph and draw a free curve through the points. A typical deviation curve is shown above.

Iron and steel become magnetized if placed within a magnetic field. This magnetic property is normally lost if the magnetic field is removed. If, however, the steel is subjected to hammering or twisting while in the magnetic field, it will become more or less permanently magnetized. The harder the steel, the more magnetism it retains.

There is relatively little soft iron in a plane except in starter casings and the like. There is also relatively little soft steel. Such as there is will have magnetism induced in it from the earth's magnetic field. A change in latitude brings about a change in relationship between the earth's field and the relatively soft steel and iron. This varies the magnetism induced in the metal and alters its influence on the compass.

In compensating an aircraft compass, the effect of disturbing magnetic fields is neutralized. In part, the disturbing influence may have come from relatively soft iron and steel. If such is the case (and there is no easy way of finding out), the compensation will not hold good for all latitudes.

AIRSPEED INDICATOR CALIBRATION

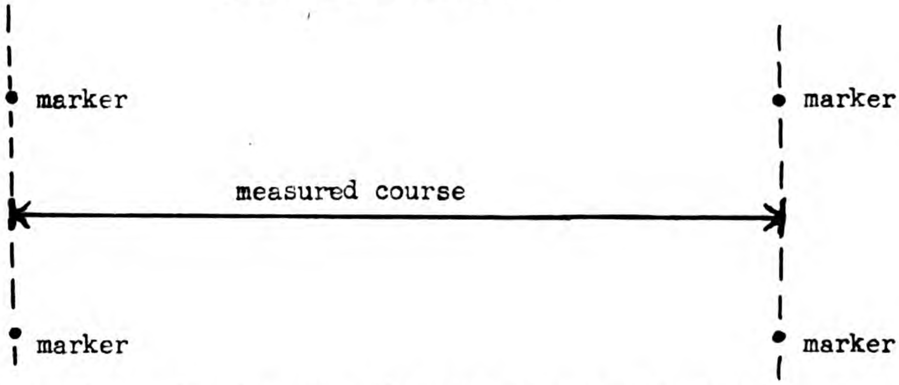


On the computer above, a pressure altitude of 500 ft. is shown set opposite + 20° C. Pressure altitude is the face reading of the altimeter when set to the 1013 millibar (29.92 inch) pressure level.

A true airspeed of 112 kts. will actually be made when the airspeed indicator reads 110.

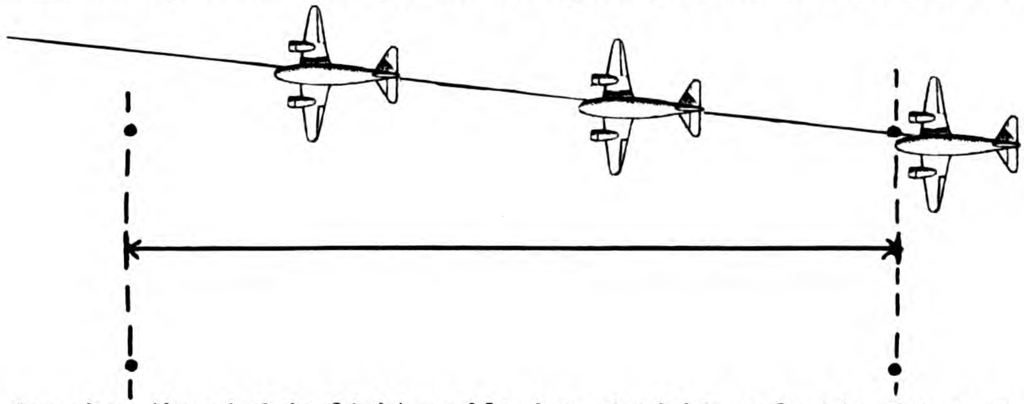
Stated in reverse order: Under this pressure-altitude and temperature condition, you expect your airspeed indicator to <u>read</u> 110 when you <u>know</u> the true airspeed is 112.

FINDING TRUE AIRSPEED



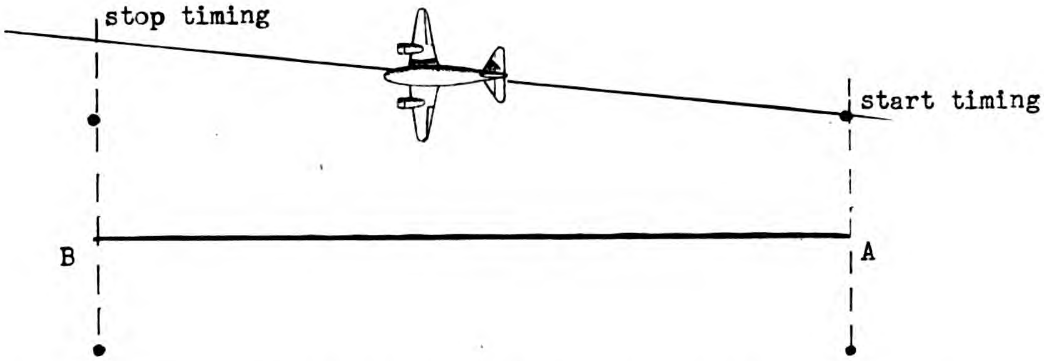
When calibrating an airspeed indicator, the true airspeed is determined by flying the plane over a measured course. The temperature and pressure altitude are recorded. Working backwards with this information, the navigator finds out what his airspeed indicator should have read during the trial run. After several such runs at different airspeeds, sufficient data is obtained to draw up a calibration chart for the airspeed indicator.

The measured course should be about 5 miles long and there should be a clear approach of about 2 miles at each end. The ends of the measured course should be clearly indicated by two markers placed at right angles to the measured course.

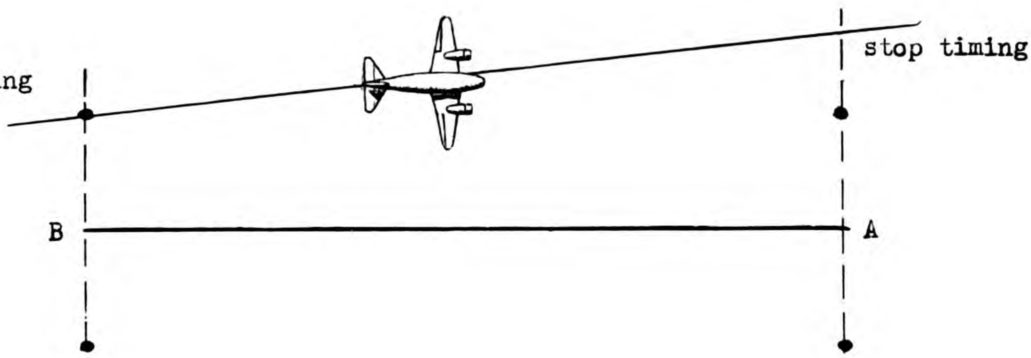


Choose a day when the wind is light or blowing at right angles to the measured course. Flights should be made at a low and constant altitude. The airspeed should be steadied down during the 2 mile approach and it too should be held constant during the run.

No allowance for wind is to be made. The heading must at all times parallel the the track between markers.



Use a stop watch to time the flight from a point in line with markers "A" to a point in line with markers "B". Note the pressure altitude, temperature and average indicated airspeed.



Repeat the procedure at the same altitude and airspeed between a point in line with markers "B" and markers "A".

Average the data obtained on each of these flights. The true airspeed in kts. is determined from this equation:

$$\text{T.A.S.} = \frac{\text{Distance in nautical miles between markers} \times 3600}{\text{Average time in seconds}}$$

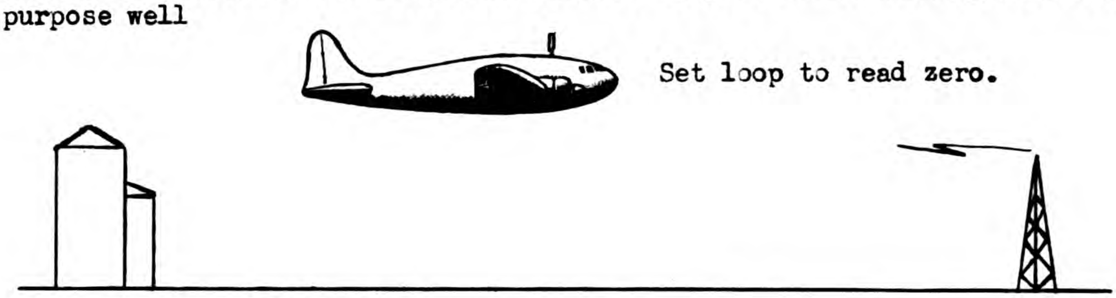
IND.	CAL.
100	102
115	116
130	132
145	145
160	158
etc.	

The entire procedure should be repeated at 15 kt. airspeed intervals until the entire airspeed range has been checked.

Using the true airspeed thus obtained, work backwards and find out what the airspeed indicator should have read. Compare these values with the airspeeds noted curing the trial runs and draw up a calibration chart such as that above.

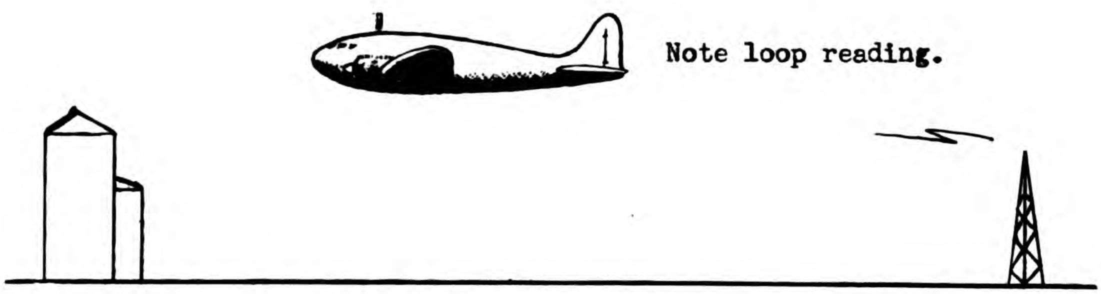
DIRECTION FINDER CALIBRATION

Select a prominent object about 30 miles from the transmitting station on which you intend to calibrate the direction finder. A good tall building will serve the purpose well



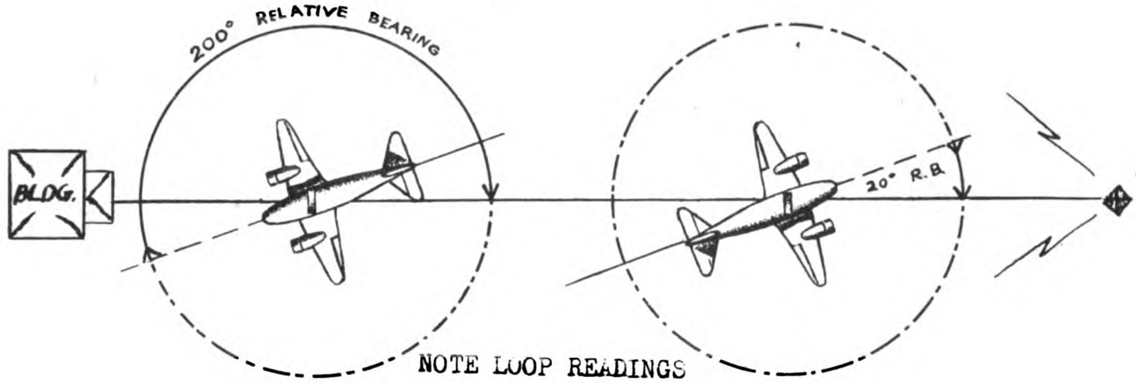
Set loop to read zero.

Choose a day when there is little wind and head directly toward the transmitter. Set the loop antenna scale to read zero when the null is positively determined.



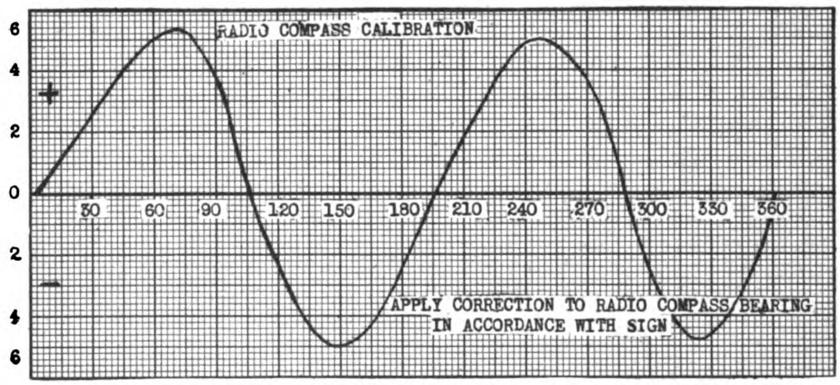
Note loop reading.

Next head directly away from the station and <u>note the reading</u> of the loop antenna scale when the null is established.



Circle around and establish a steady heading 20° left of the heading previously maintained toward the transmitter. Watch the null closely. Read the null the instant the plane crosses the track connecting the building and transmitter, and obtain the precise heading of the plane.

The true heading of the plane plus the loop reading should add up to the true bearing of the transmitter from the building. Any difference noted is either an additive or subtractive loop correction.



This procedure is repeated a number of times with the station bearing at increasing relative angles until sufficient information is available to plot a curve of errors similar to a compass deviation curve.

This book may be kept